JTIDS Shipboard Antennas

J. Boyns
Microwave/Millimeter Wave Branch,
Code 753
and
JTIDS Project Office, Code 451

Technical Document 2797
April 1995

Naval Command, Control and
Ocean Surveillance Center
RDT&E Division

San Diego, CA
92152-5001

Technical Document 2797
April 1995

JTIDS Shipboard Antennas

J. Boyns
Microwave/Millimeter Wave Branch, Code 753

and

JTIDS Project Office, Code 451

NAVAL COMMAND, CONTROL AND OCEAN SURVEILLANCE CENTER RDT&E DIVISION
San Diego, California 92152–5001

K. E. EVANS, CAPT, USN
Commanding Officer

R. T. SHEARER
Executive Director

ADMINISTRATIVE INFORMATION

The work detailed in this document was performed by the Naval Command, Control and Ocean Surveillance Center, RDT&E Division, Microwave/Millimeter Wave Branch, Code 753, and JTIDS Project Office, Code 451, for Space and Naval Warfare Systems Command, Program Executive Office for Space, Communications and Sensors, PMW–159–3D, Washington, DC 20363–5100. Funding was provided under program element 0205604N and accession number DN213105.

Released by
R. W. Major, Head
Microwave/MMW Branch

D. P. Andersen, Head
JTIDS/LINK 16 Business Manager

Under authority of
J. E. Griffin, Head
Electromagnetic Systems Division

H. F. Wong, Head
Integration and Interoperability Division

PS

CONTENTS

Figures

Tables

INTRODUCTION

The involvement of Naval Command, Control and Ocean Surveillance Center, RDT&E Division (NRaD) Code 753 (formerly Naval Ocean Systems Center (NOSC) Code 8112) in the Joint Tactical Information Distribution System (JTIDS) program began in the first quarter of FY 84. The task for that time period was to perform a feasibility analysis for Radio Frequency (RF) transmission in the Southern California (SOCAL) area using JTIDS terminals. The analysis was concerned with the transmission path from NRaD Bldg. 600 to Marine Corps Tactical System Support Activity (MCTSSA) Camp Pendleton via Fleet Combat Direction System Support Activity (FCDSSA). The purpose of this task was to determine the size and location of antennas necessary to provide a usable link using the available JTIDS transmitting and receiving equipment.

The next task was to provide an antenna that could be installed on the mast of the USS *Constellation* (CV64) for use in conducting Electromagnetic Interference/Electromagnetic Compatability (EMI/EMC) studies. An eight-element array was designed, fabricated, tested, and installed by NRaD and shipboard personnel. This antenna remained on the USS *Constellation* (CV 64) for 2 months.

Monitoring of the antenna contract with International Telephone and Telegraph (ITT) was the next task. Study of available documents was the main concern of this task as there were no design reviews or demonstrations by the contractor. Mockups of the hardware design were done by NRaD personnel based on limited information available.

Development of an alternate design was undertaken in FY 85. The approach that was selected consisted of a bicone fed with an array of elements or probes as opposed to the usual single exciter used in a common bicone. The aperture was designed using a software tool called NECBSC2 (Numerical Electromagnetics Code) developed by Ohio State University. Based on predictions made using this program, a one-fifth scale model of the biconical antenna was fabricated and tested.

The next step in the development of the biconical antenna was to fabricate a full-scale model. The antenna was fabricated from solid aluminum, was 63 inches in diameter, and weighed nearly 400 pounds. This antenna used 16 probes or elements to excite the bicone. Because of a weight limit on the order of 100 pounds, this antenna was again fabricated using metallized fiberglass techniques. The bicone structure was fabricated by Microwave Specialty Corporation (MSC) of San Marcos, CA. The weight of this antenna was less than 100 pounds, but it was not designed for the shipboard environment.

The size of the 63-inch bicone was prohibitive due to the need for service personnel to be able to assess the Tactical Air Navigation (TACAN) antenna mounted above the bicone. A smaller size bicone was designed and fabricated. This antenna was 43 inches in diameter. The first model was again fabricated from solid aluminum and produced a structure weighing on the order of 300 pounds. This antenna was configured to allow the use of both 16 and 12 probes to excite the bicone. Sixteen probes in the smaller sized bicone provided tight coupling between elements that caused degradation to the radiation patterns. Based on satisfactory results produced by this antenna using 12 probes, a metallized fiberglass version was fabricated and tested.

The contract with ITT was canceled in FY 87 and the go ahead was given to NRaD to design, fabricate, test, qualify, and install an antenna for shipboard use based on the bicone approach. The antenna was produced and qualified, and a military designation was applied for. The reduced-size bicone with 12 probes and constructed from metallized fiberglass became the AS-4127/URC-107(V) (hereafter known as the AS-4127) JTIDS Shipboard Antenna. The JTIDS system underwent technical/operational evaluation in FY 94 using this antenna, and the program was declared a success.

Installation plans for the AS-4127 included a receive-only antenna that was to be mounted one-third of the height of the AS-4127 below the AS-4127. The purpose of this antenna was to act as an alternate source when the AS-4127 suffered a loss of signal due to multipath. The antenna selected for this purpose was the AS-177B/URC (hereafter known as the AS-177), which was an Identification Friend or Foe (IFF) antenna. Tests made by NRaD personnel demonstrated that the AS-177 was not adequate to perform the intended function due to its limited bandwidth. A survey was made of the government supply system that indicated there was a limited number of AS-177s available with no contract in place for obtaining additional items. Based on this information, NRaD personnel designed, fabricated, tested, and qualified an antenna that could be used as the receive-only antenna with the AS-4127. This antenna was designated the AS-4400/URC (hereafter known as the AS-4400) JTIDS Shipboard Antenna and was known as the "Stand Alone Antenna."

The mounting configuration of the AS-4127 dictated the design of the next generation of JTIDS antenna. This antenna was commonly called the "Wrap Around Antenna" and was assigned the military designation of AS-4127A/URC-107(V) (hereafter known as the AS-4127A). This antenna, currently being designed and fabricated by NRaD personnel, consists of 16 double dipole elements mounted around a cylinder with a protecting radome having Frequency Selective Surface (FSS) properties. It is currently undergoing environmental testing.

The next generation of JTIDS antenna will be designated the AS-4127B/URC-107(V). This antenna will consist of the AS-4127A antenna fed with phased array techniques to provide flexibility to the JTIDS system. A study of feed techniques is to start in FY 96.

Another task involved a decoupling study between the JTIDS antennas and the TACAN antenna. The results of this task produced a decoupling choke that was attached to the underside of the outer rim of the TACAN antenna. The use of this choke reduced the coupling between antennas to less than –40 dB.

A near-field test device was developed by NRaD personnel to provide a means of determining the operating condition of the AS-4127 in the field without removing the antenna and transporting it to a test facility. This device could be used by service or shipyard personnel to determine if an antenna's performance had degraded without the cost of removing and shipping the antenna for evaluation. The test device can also be used by assembly personnel to determine if an AS-4127 has been properly assembled prior to being transported to the test range. It has been proposed that a near-field device be developed for use with the AS-4127A and AS-4127B antennas.

A mockup of the DDG 72 Flight II O10 Level was fabricated to determine performance of the AS-4127A in that environment. Other combinations of antenna arrangements were also tested. This mockup is to be permanently installed on NRaD Building 583 in the near future for further evaluation of antenna combinations.

An antenna installation was made at the NRaD Building 600 System Integration Facility (SIF). Installations were also made at San Clemente Island and the Pedro Tower to extend the capabilities of the SIF. The SIF site included AS-4127 and AS-4400 antennas, the San Clemente Island site included two AS-4400 antennas, and the Pedro Tower site included one AS-4400 antenna.

FEASIBILITY ANALYSIS FOR RF TRANSMISSION IN THE CALIFORNIA AREA USING JTIDS TERMINALS

The feasibility analysis task was provided by the former NOSC Code 831 in the first quarter of FY 84. It was imperative to explore alternative Tactical Digital Information Link J [Link 16](TADIL-J) testbed configurations as a possible means of reducing risk and cost. The objective of the analysis was to determine the feasibility of the live JTIDS RF operation in the testbed versus the use of a contained artificial RF terminal. Terminals were to be placed at NRaD Building 600 third floor, FCDSSA Building 24 at E-2C Lab, and MCTSSA in TAOC-85 (Tactical Air Operations Center), Camp Pendleton.

PRIMARY CONCERNS OF THE STUDY

1. What will the quality and availability of the RF paths be?
2. Does the geometry pose special problems associated with near-far transmitter/receiver phenomenon?
3. The JTIDS DTDMA net operation requires all participants have simultaneous access to all transmissions. Will the geometry associated with NRaD, FDCSSA, and MCTSSA locations permit such operations?

ANALYSIS OUTPUT

1. A recommended antenna configuration at each terminal site.
2. An estimated cost for site engineering, antenna/cable fabrication or procurement, antenna installation, and acceptance checkout.
3. A detailed SOCAL layout showing azimuths, distances, and expected beamwidths.

OUTPUT

1. The first set of calculations involved line-of-sight calculations from NRaD Building 600 to MCTSSA Camp Pendleton. The receive sensitivity used for these calculations was –95 dBm. Using 220 feet as the elevation of the roof of NRaD Building 600 and 40 feet as the ground level elevation of MCTSSA, it was determined that an antenna height of 172 feet would be required at MCTSSA to provide terrain clearance. The distance from NRaD to MCTSSA was determined to be 38.33 miles, providing a path loss of 129.9 dB, which would require parabolic antennas at each location of 1.17 foot diameter.
2. To construct an antenna tower 172 feet at MCTSSA apparently was not feasible, so alternate calculations were made. These calculations were made using a passive reflector mounted on the base of the 60-foot parabola tower located at the south end of the NRaD Microwave Antenna Range. A 30-dB margin in signal level was required. As a result, the recommended antenna sizes were a 10-foot passive reflector at the 60-foot parabola tower, a 4-foot parabola at Building 600, an omnidirectional antenna at FCDSSA, and a 4-foot parabola at MCTSSA. The system was never implemented.

EMI/EMC ANTENNA

In FY 84 a sample of the Radio Frequency (RF) environment was needed for the area on the mast below the TACAN antenna where the JTIDS shipboard antenna would be installed. The sampling was to be done on the USS *Constellation* (CV 64). An eight-element array was assembled from available components for making the required installation on the ship's mast. The array consisted of eight double-dipole elements previously used in an L-band phased array, uniform power dividers, and equal length cables. Figure 1 shows the assembled antenna, and figure 2 shows the antenna separated into two sections. The antenna was designed to clamp around the ship's mast. Figure 3 is a view of a mockup of the mast of the USS *Constellation* (CV 64) with the EMI/EMC antenna mounted below a mockup of the TACAN antenna. The antenna was installed by NRaD personnel and a low-loss cable was run by NRaD and ship's personnel from the antenna to the radio room. The antenna remained aboard the ship for 2 months and provided usable data.

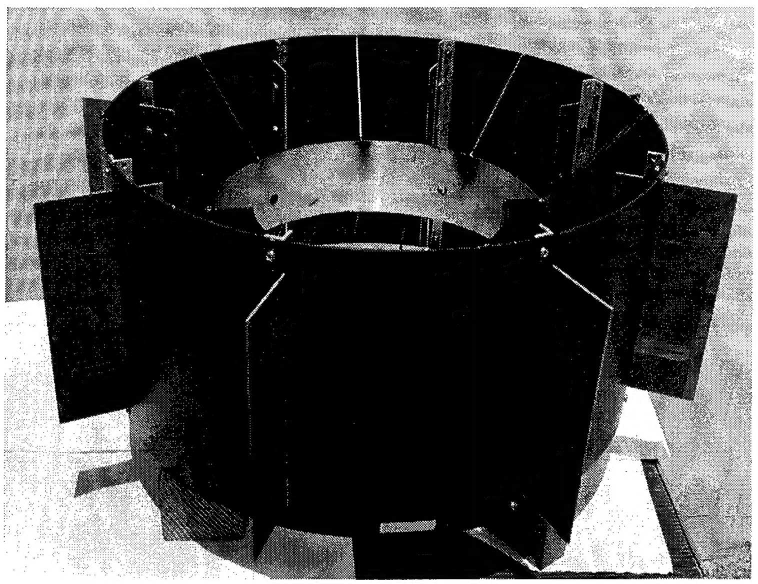


Figure 1. Eight-element EMI/EMC array antenna.

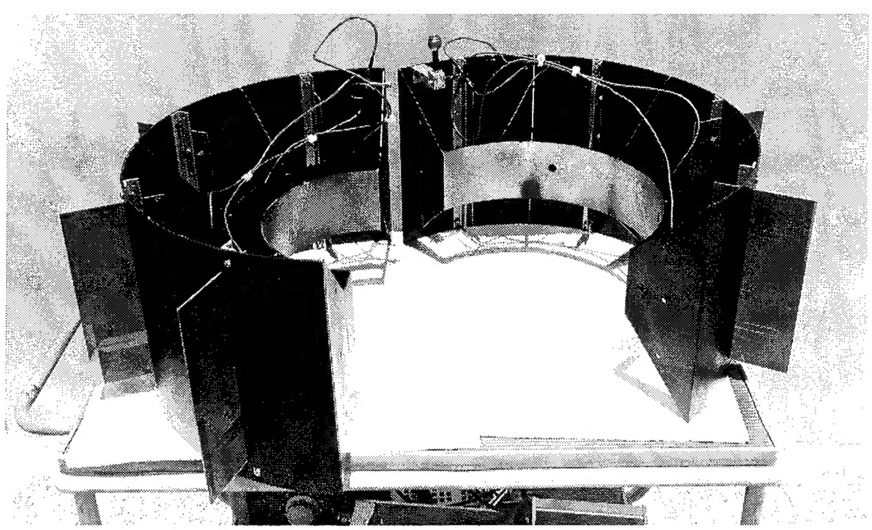


Figure 2. EMI/EMC antenna separated into two sections.

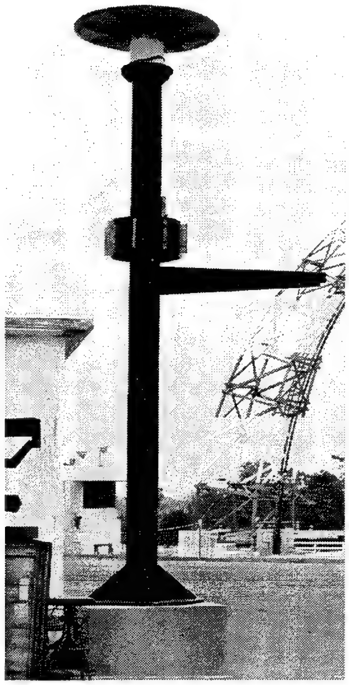


Figure 3. EMI/EMC antenna on USS *Constellation* (CV 64) mast mockup.

ANTENNA MOCKUPS

ITT had been awarded a contract to develop the shipboard antenna for the JTIDS system. NRaD personnel were given the task of monitoring this contract. The only information available to NRaD personnel was a limited amount of a general nature. Very little information had been published. No design reviews were held; nor were there any hardware demonstrations.

To acquaint themselves with how the ITT antenna could perform, a mockup of the antenna was fabricated by NRaD personnel. Figure 4 is a view of the ITT antenna mockup. A mockup of the TACAN antenna was also fabricated. The mockup of the TACAN antenna is shown in figure 5. This mockup was designed to produce the scalloped pattern characteristic of the TACAN antenna. Since this was not a functional antenna, the pattern that was produced was for a given instant in time.

ITT eventually gave NRaD the hardware that had been produced. Figure 6 shows the ITT antenna that had been assembled by NRaD personnel for evaluation.

AS-4127/URC-107(V) JTIDS SHIPBOARD ANTENNA

While the monitoring of the ITT contract was progressing, NRaD was given the task of designing an alternate approach for the shipboard antenna for JTIDS. The alternate design consisted of a biconical antenna illuminated by multiple feeds. The requirement for providing support for the TACAN antenna limited the choice of antennas to those that would mount around the mast. To test the design, a one-fifth scale model was designed and fabricated. The elevation aperture was modeled on a VAX computer using NECBSC2 developed by Ohio State University. Figure 7 shows the section of the elevation aperture of the one-fifth scale model. Based on the NECBSC2 calculations and experimental investigations for the section of the one-fifth scale model, a complete one-fifth scale model bicone was designed and fabricated from solid aluminum. This antenna is shown in figure 8. The parameters

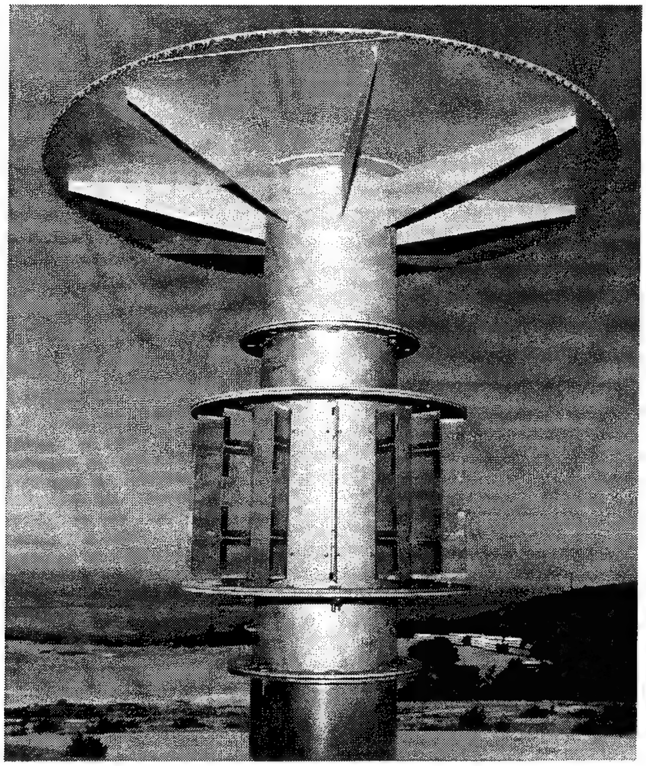


Figure 4. ITT antenna mockup.

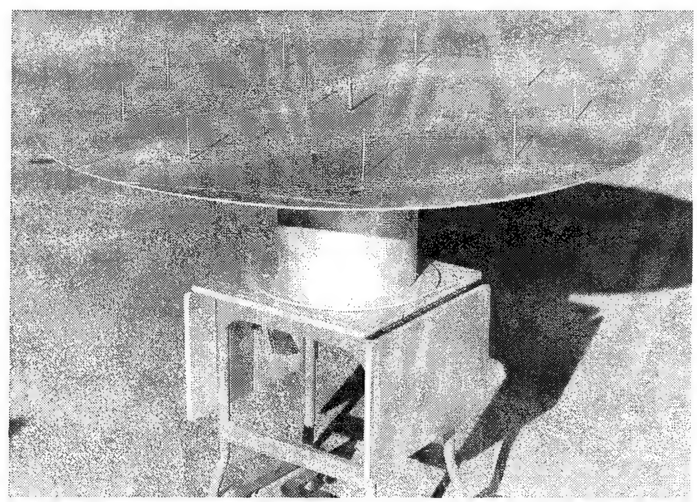


Figure 5. Mockup of TACAN antenna.

produced by this antenna were very close to those predicted by NECBSC2. This antenna was illuminated by 16 feed points or probes equally spaced and located one-quarter wavelength from the back wall. The antenna was uniformly fed in phase and amplitude.

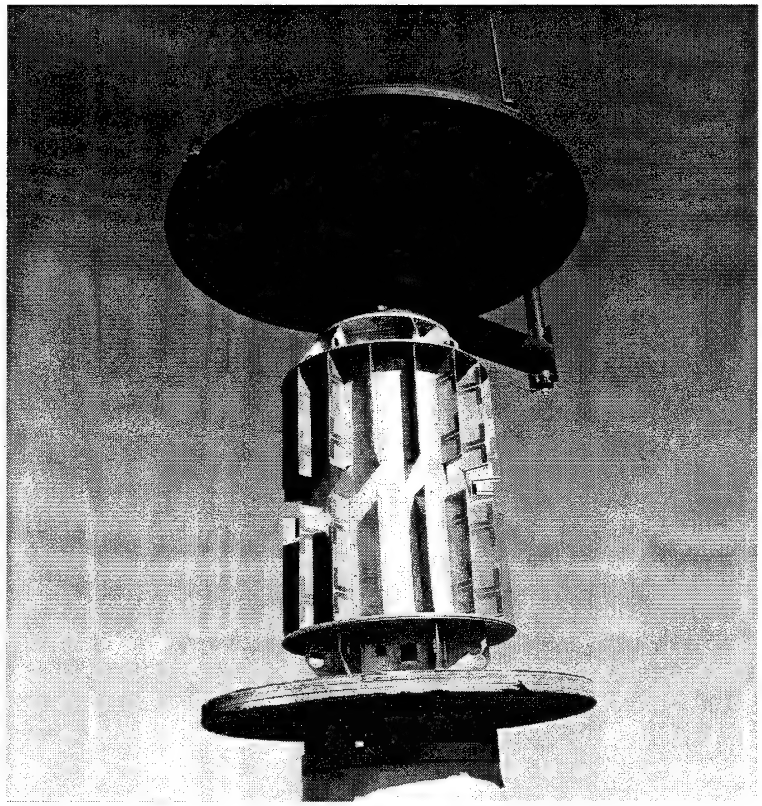


Figure 6. ITT antenna.

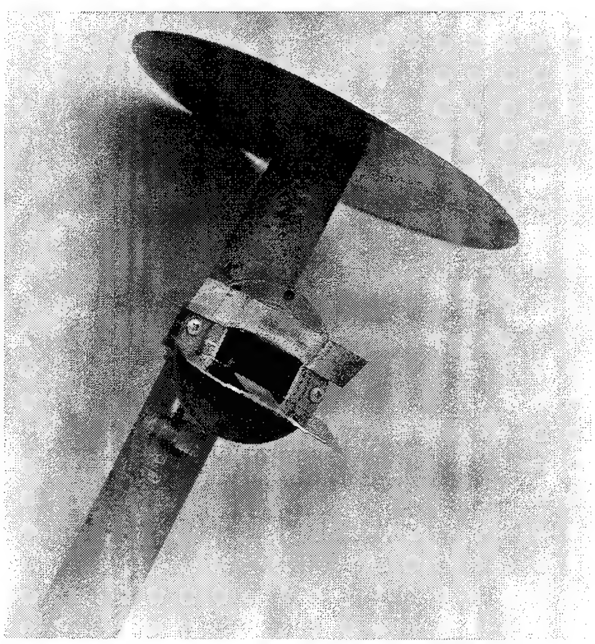


Figure 7. Section of one-fifth scale model elevation aperture.

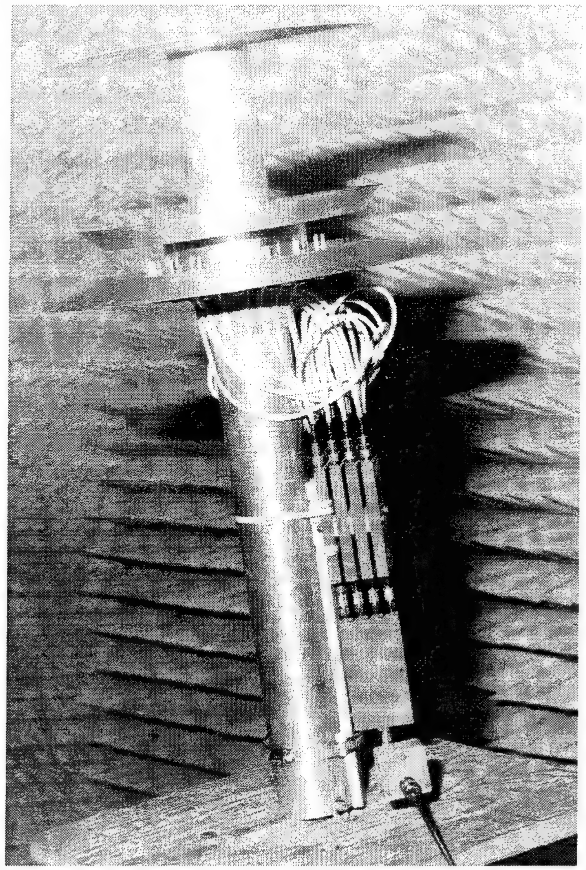


Figure 8. One-fifth scale model bicone antenna.

The encouraging results from the one-fifth scale model bicone antenna led to the development of a full-scale model. As with the scale model, a section of the elevation aperture was fabricated and tested prior to the fabrication of a complete bicone. Figure 9 is a view of the section of the full-scale bicone. Figure 10 shows measured elevation patterns from the section of the elevation aperture. The complete antenna was made of solid aluminum, was 63 inches in diameter, and weighed more than 300 pounds. Sixteen uniformly fed probes were used to illuminate the bicone. This antenna is shown in figure 11.

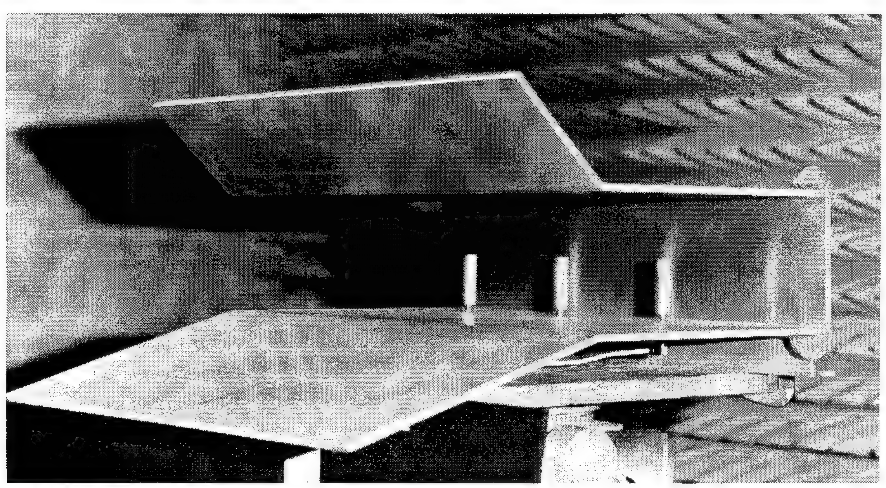


Figure 9. Section of elevation aperture.

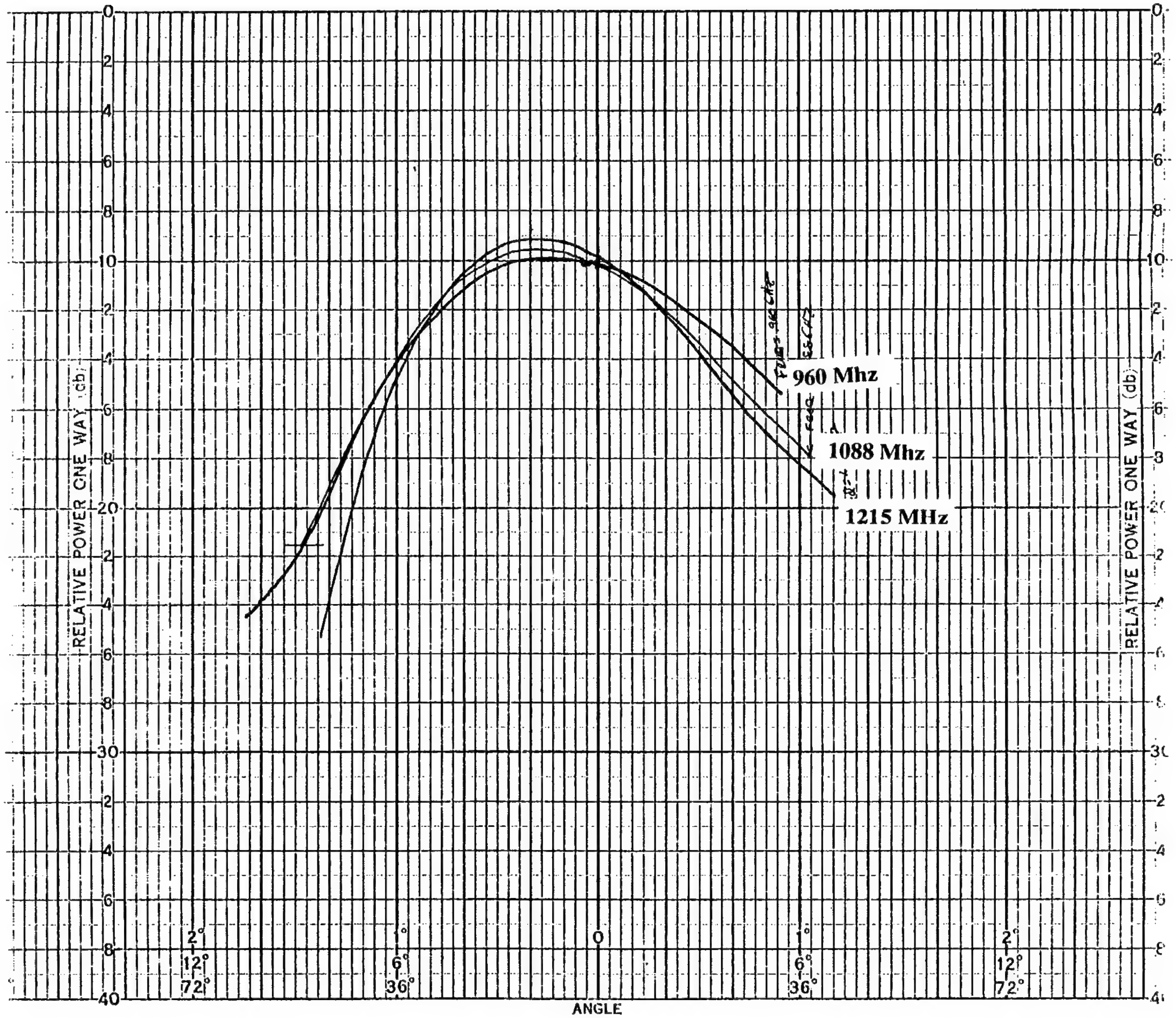


Figure 10. Measured elevation patterns from aperture section.

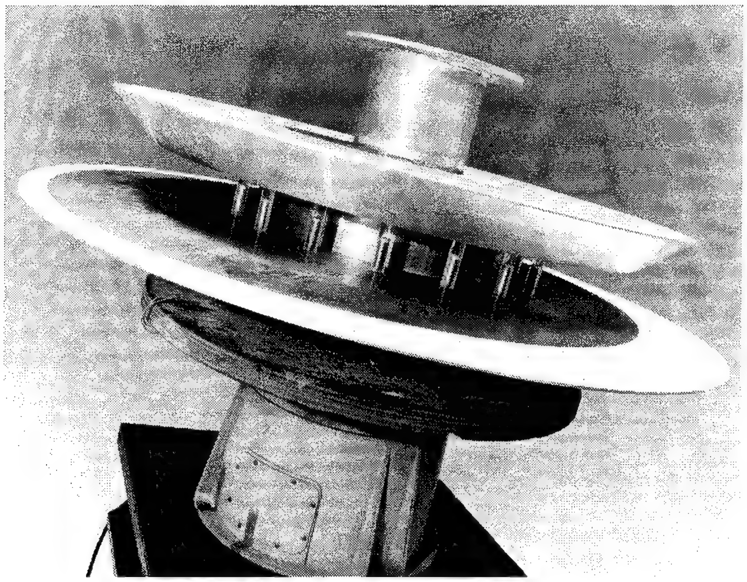


Figure 11. 63-inch-diameter aluminum bicone (full scale).

The specification for the JTIDS shipboard antenna required that the weight be limited to 100 pounds. The selected approach for reducing the weight was to fabricate the antenna using metallized fiberglass techniques. Figures 12 and 13 show the antenna that was fabricated in this manner. This particular antenna had a fiberglass radome. The total weight was less than 100 pounds, but the antenna was not designed to meet shipboard environmental requirements. Figure 14 shows the mounting arrangement for the probes located one-quarter wavelength from the back wall of the bicone.

When the bicone was installed below a TACAN antenna, a requirement existed that the TACAN antenna would require routine maintenance. This was accomplished by a technician who would climb the ship's mast and reach around the bicone to the TACAN antenna. A bicone of 63-inch diameter made the task very difficult. Efforts were then started to reduce the size of the bicone. As a result, a 43-inch bicone was designed and fabricated from aluminum. This antenna, shown in figure 15, weighed around 300 pounds. It was designed with two arrangements of probes; one consisting of 16 and the other of 12. Reduction in the diameter of the bicone placed the probes closer to each other than one-half wavelength, which caused close coupling and degraded the radiation patterns. By using 12 probes, the spacing was again on the order of one-half wavelength. To reduce the weight, a model was fabricated using metallized fiberglass techniques. This antenna is shown in figure 16.

Based on the favorable results of the above study, a 43-inch bicone was designed and fabricated for meeting shipboard qualifications. The antenna qualified for shipboard installation is shown in figure 17. A cut-away view of the antenna is shown in figure 18. The specifications for the AS-4127 are given in table 1. Measured radiation patterns are shown in figure 19 at 1.045 GHz. Figure 20 shows measured Voltage Standing Wave Ratio (VSWR).

One of the first installations for the AS-4127 was on top of NRaD Building 600. This installation is shown in figure 21 and includes the AS-4400, which is the recommended arrangement for each installation. Other known installations of the antenna are given in table 2.

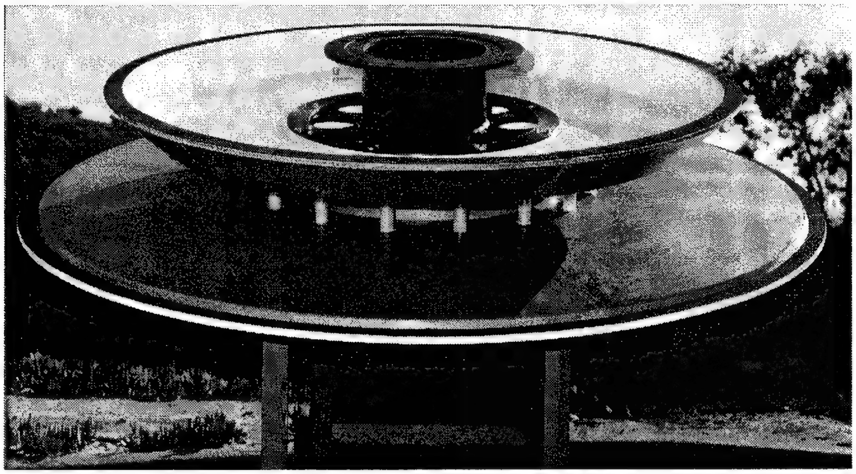
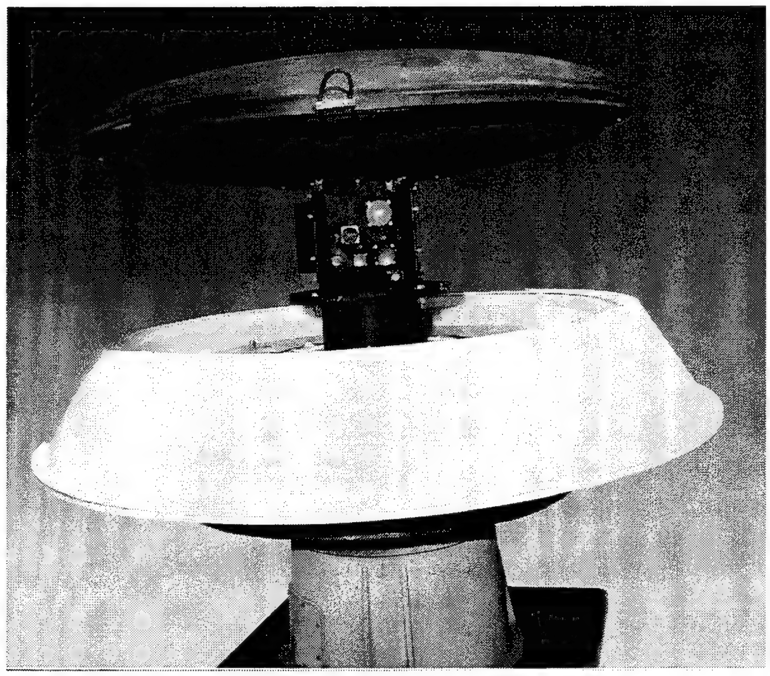


Figure 12. 63-inch-diameter metallized fiberglass bicone.

Figure 13. 63-inch-diameter metallized fiberglass bicone with radome.



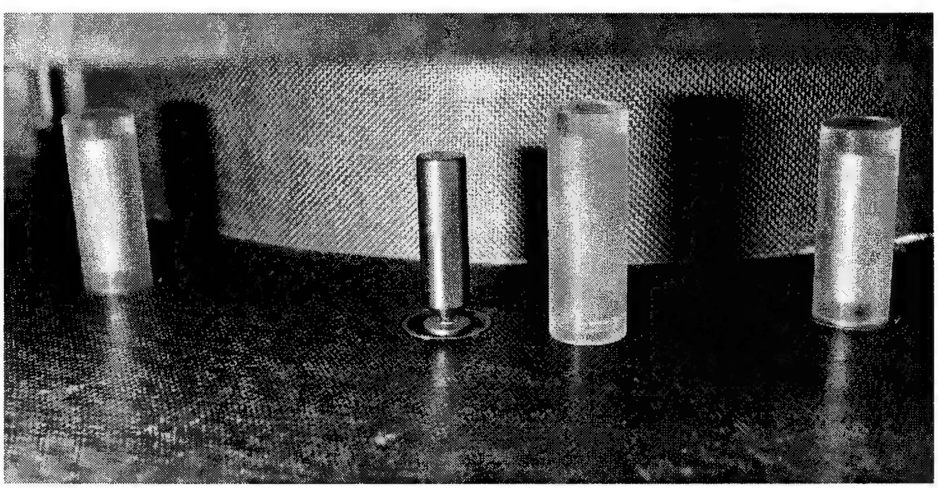


Figure 14. Probe mounting arrangement inside bicone.

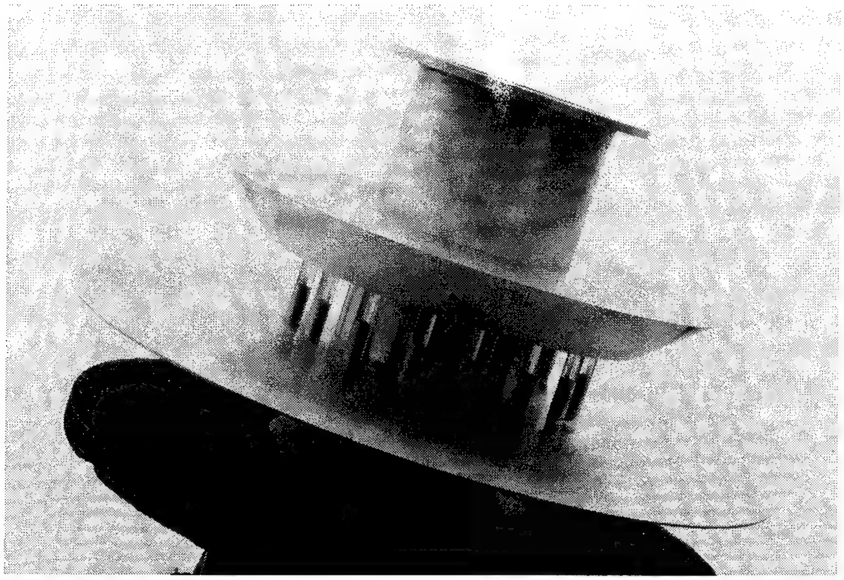


Figure 15. 43-inch aluminum bicone.

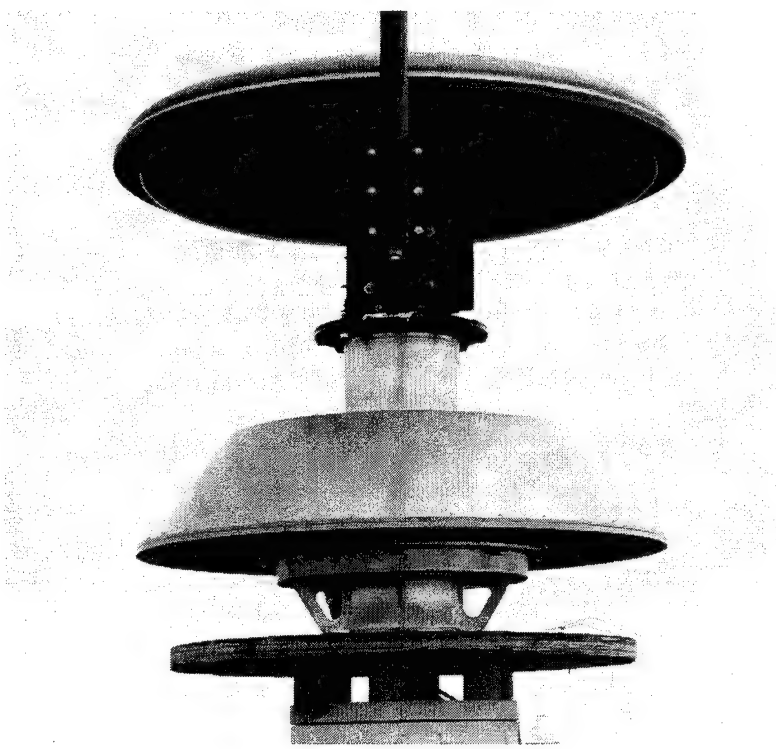


Figure 16. 43-inch metallized fiberglass bicone.

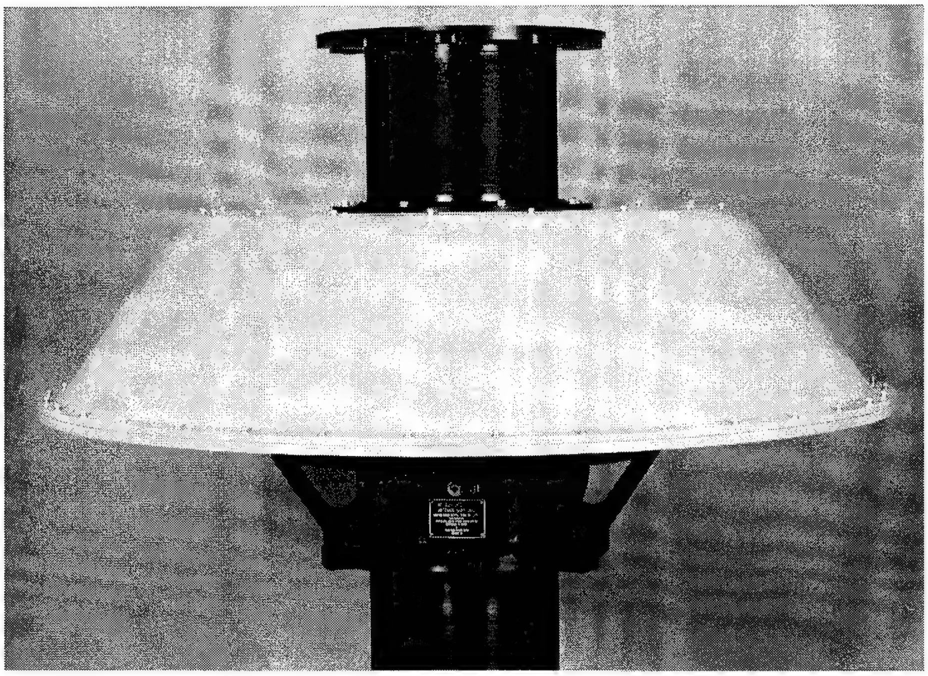


Figure 17. Shipboard-qualified AS-4127 antenna.

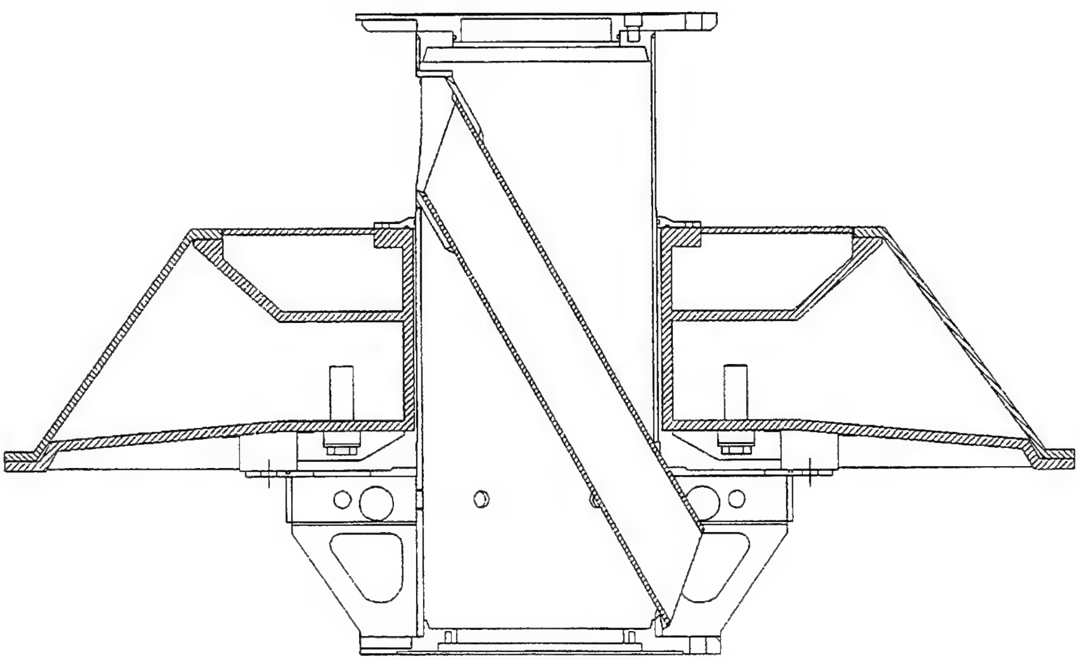


Figure 18. Cut-away view of AS-4127 antenna.

Table 1. AS-4127/URC-107(V) specifications.

Parameter/Nomenclature	Specification/Dimension	
Manufacturer	Naval Ocean Systems Center (now NRaD)	
Part Number	AS-4127/URC-107(V)	
Size	Uncrated	Crated
diameter/width, depth	47 in-diameter	54 x 64 in
height	28 in	34 in
Weight	133 lb	250 lb
Volume	25.14 ft^3	68 ft^3
Operation	Continuous (24 hours/day)	
Temperature operating nonoperating	 –28 to +65 °C –62 to +71 °C	
Humidity	95% including condensation as water or frost	
Radiation Pattern azimuth elevation	 Omnidirectional Tapered hemispheric	
Frequency Range	960 to 1215 MHz	
Minimum Gain	2.0 dBi	
Polarization	Vertical	
Input Impedance (RF port, coaxial)	50 ohms	
RF Power Input peak average	 1200 watts 140 watts	
Voltage Standing Wave Ratio (VSWR)	2.1:1 (maximum)	
Intermodulation Products	63 dB (below) primary signal level	
Isolation from TACAN (with TACAN Choke installed)	40 dB	

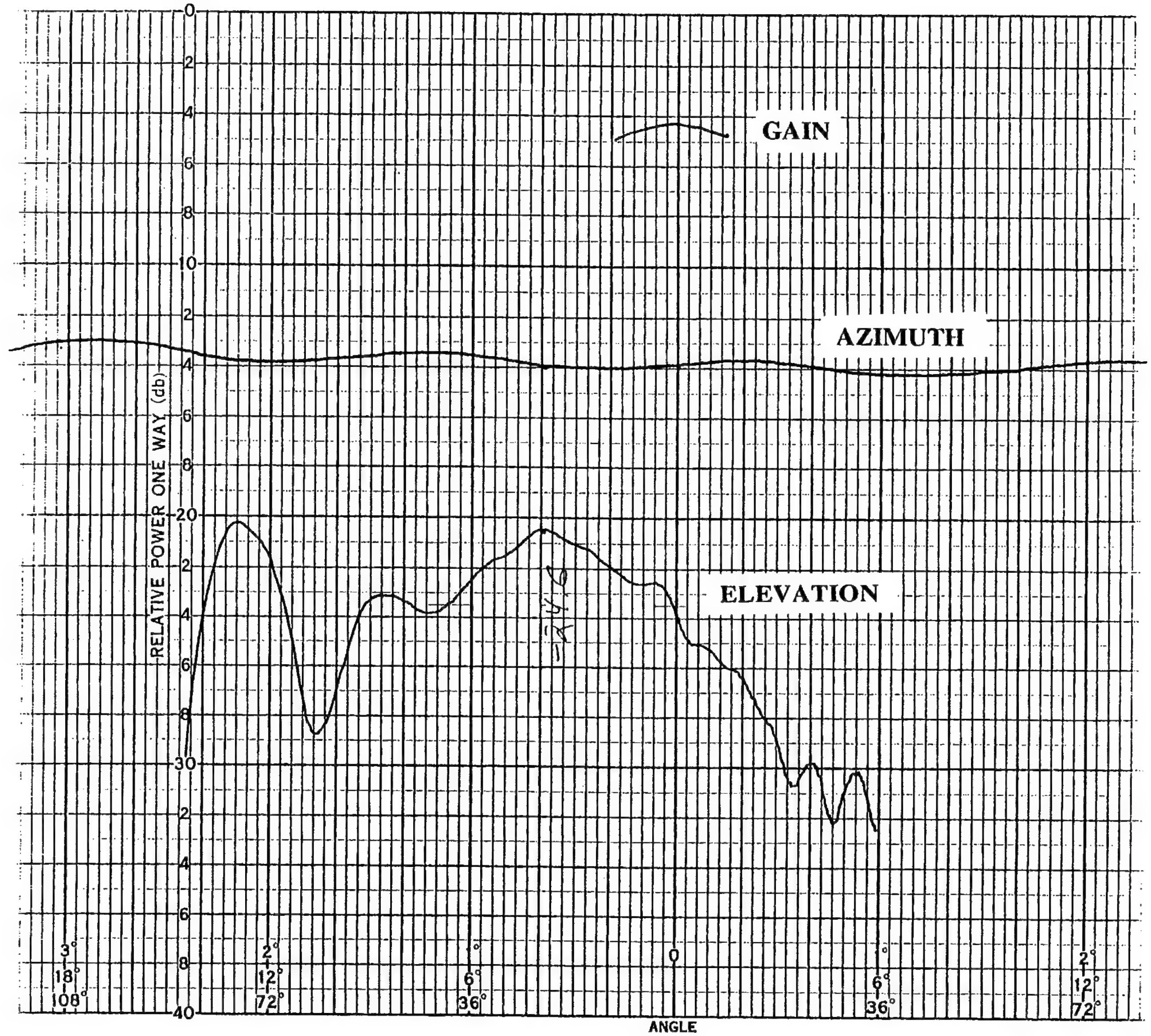


Figure 19. Measured radiation patterns for AS-4127 at 1.045 GHz.

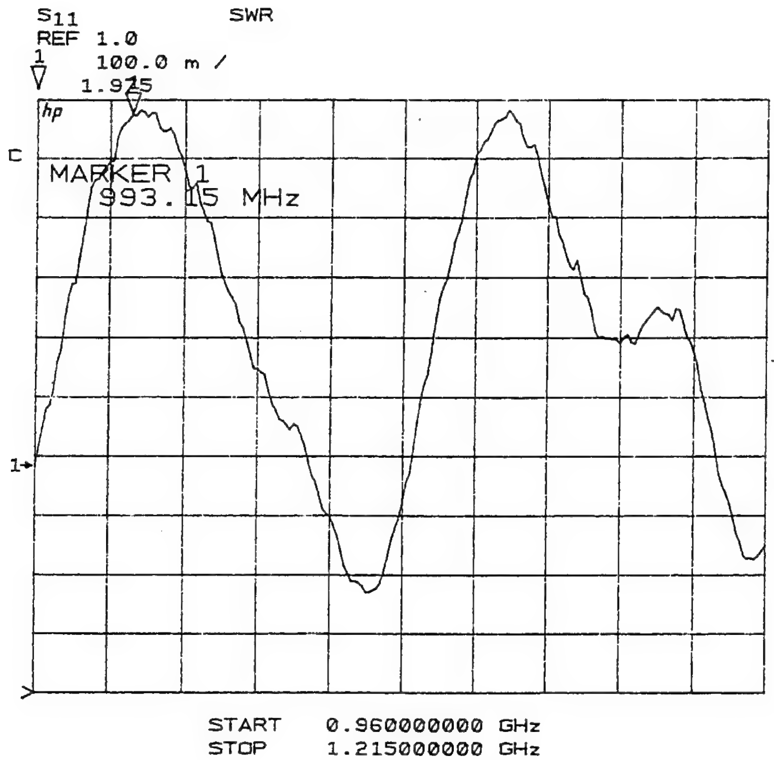


Figure 20. Measured VSWR for AS-4127.

AS-4400

AS-4127

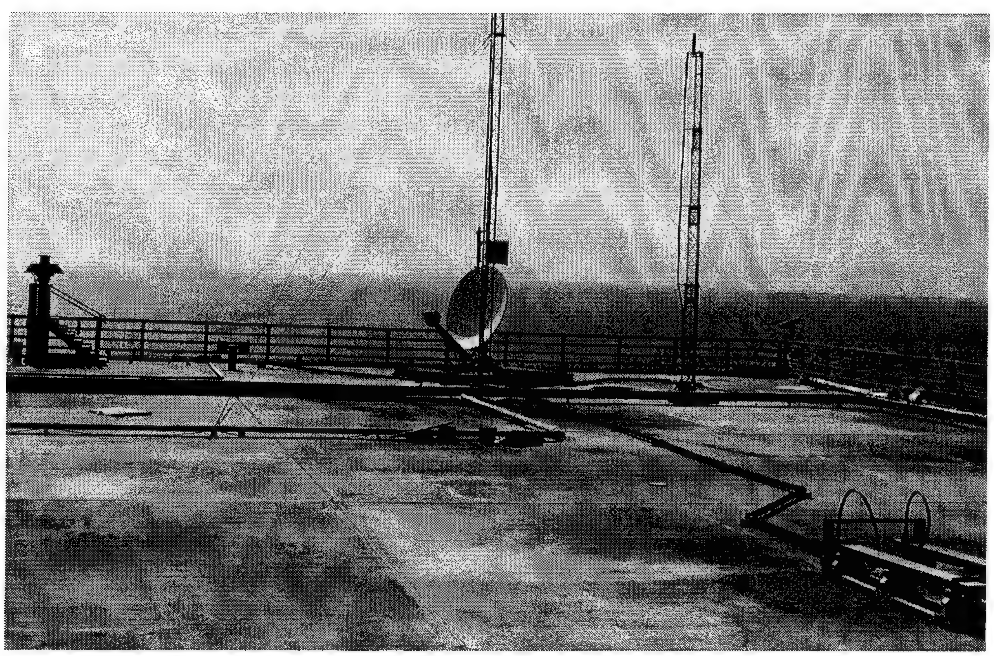


Figure 21. AS-4127 installation on NRaD Building 600.

Table 2. AS-4127/URC-107(V) JTIDS antenna installation status.

Serial Number	Location
EDM-1	NRaD
EDM-2	Dam Neck, VA
A001	Wallops Island, VA
A002	UK
A003	NRaD (was on the USS *Wainwright* (CG 28))
A004	NRaD (was on the USS *Yorktown* (CG 48))
A005	NRaD
A006	GEC Marconi
A007	NRaD
A008	NRaD Building 600 SIF
A009	UK
A010	UK
A011	USS *Carl Vinson* (CVN 70)
A012	France
A013	USS *Arkansas* (CGN 41)
A014	NISE West (was on the USS *Antietam* (CG 54)
A015 – A044	Shipped to NISE West

AS-4400/URC JTIDS SHIPBOARD ANTENNA

To avoid a loss of signal due to multipath, a receive-only antenna is included in the JTIDS installation. This antenna is usually located below and one-third of the height of the AS-4127 as shown in figure 22. The antenna selected for this purpose was the AS-177B/URC, an IFF antenna. Evaluation of this antenna determined that it did not provide adequate performance over the entire JTIDS bandwidth. A check with the government supply system indicated that 10 new AS-177s were available and 10 more had been turned in for repair. There was no contract in place for obtaining additional antennas.

Because of the lack of an antenna to fill the need for a receive-only antenna, NRaD personnel designed, fabricated, tested, and qualified an antenna that became the AS-4400/URC. This antenna, shown in figure 23, is an array of collinear dipoles in circular waveguide. The characteristics of this antenna are given in table 3.

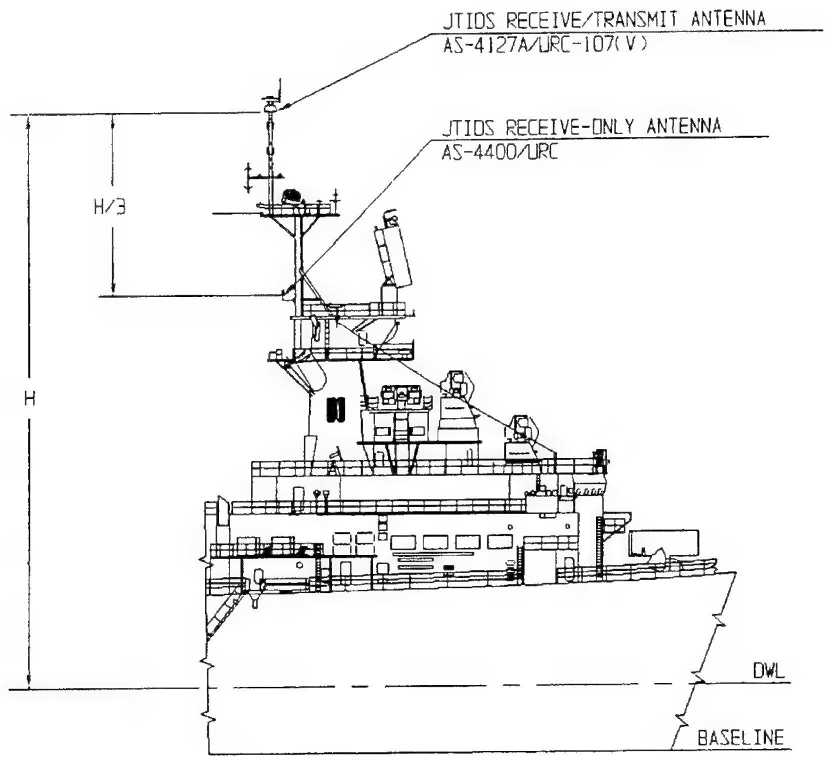


Figure 22. JTIDS shipboard antenna arrangement.

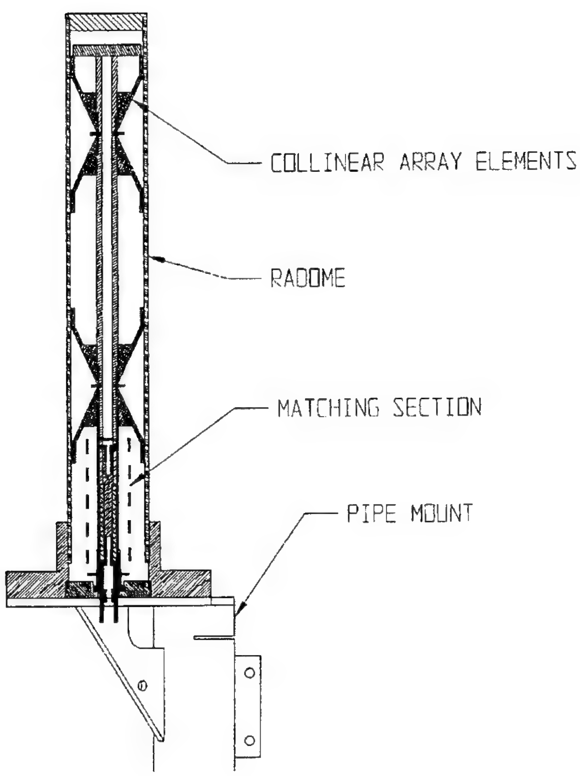


Figure 23. Array of collinear dipoles in circular waveguide.

Table 3. AS-4400/URC performance characteristics.

Electrical	
Frequency	9600 – 1215 MHz
Polarization	Vertical
Impedance	50 ohms
VSWR	1.9:1 maximum
Gain	2.5 dBi minimum
Elevation Coverage Half Power Beamwidth	30 degrees with peak at horizon
Azimuth Coverage	Omnidirectional ±0.75 dB
Power Rating	Peak 1.2 kW Average 149 W
Input Connector	Type N Jack (Female) M39012/03–0012
Environmental	
Vibration	MIL-STD-167, Type 1
Wind	100 knots, maximum, with 4.5 lb/sq ft ice load
Temperature/Humidity	MIL-STD-2036
Mechanical	
Overall Dimensions	2 3/8-inch diameter, 17 3/4-inch height, 6-inch-diameter base
Weight	5 pounds
Mounting	With supplied pipe (nominal 1 1/2-inch or 1.900 inch O.D.) mount (adds 5 1/4-inch height), or four 5/16 bolts on a 4 3/4-inch bolt circle

Assignment of Joint Electronics Type Designation System (JETDS) nomenclature for this antenna was received on 7 December 1994. Installation authorization from Program Executive Officer (PEO), Space, Communications and Sensors (SPAWAR) PMW 159, was received 22 September 1994.

Figure 24 is a view of the antenna qualified for shipboard installation.

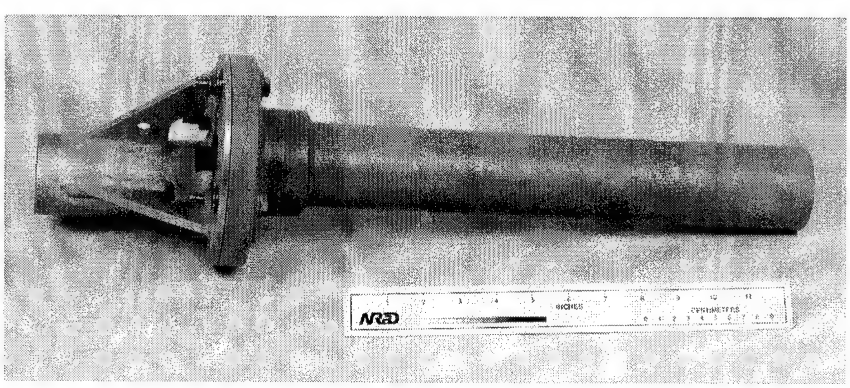


Figure 24. AS-4400/URC JTIDS shipboard antenna.

Known installations of the antenna are listed in table 4.

Table 4. AS-4400/URC antenna installations.

1 Brassboard	NRaD Building 600 SIF
2 EDM	San Clemente Island
3 EDM	San Clemente Island
4 EDM	USS *Carl Vinson* (CVN 70) – MLSE Van
5 EDM	USS *Carl Vinson* (CVN 70) – MLSE Van
6 EDM	Pedro Tower
7 EDM	Submarine Emergency
8 EDM	USS *Ticonderoga* (CG 47)
9 EDM	USS *Ticonderoga* (CG 47)
10 EDM	Qualification
11 EDM	Qualification
12 EDM	Spare
A001 – A038	NISE West
A039 – A042	NRaD

AS-4127A/URC-107(V) JTIDS SHIPBOARD ANTENNA

The mounting system for the AS-4127 dictated that the antenna could only be mounted at the top of a mast, although additional antennas such as TACAN could be mounted piggy-back. Surface ships of the DDG 72 class have a mast configuration that is not strong enough to support the additional weight of the AS-4127. Because of this deficiency, it was neccessary to provide an antenna capable of being clamped around a mast that did not weigh more than 100 pounds. Personnel at NRaD designed, fabricated, tested, and qualified an antenna for this purpose. The antenna, assigned the military nomenclature AS-4127A/URC-107(V) on 24 August 1994, was qualified via environmental and high-power testing in March 1995. The delivery of the first production model for installation on the USS *Mahan* (DDG 72) is scheduled for July 1995.

The AS-4127A is an array of 16 printed circuit double-dipole radiating elements mounted around a cyclinder (see figures 25 and 26).

The antenna is uniformly illuminated using equal length cables and power dividers having equal phase and amplitude. The antenna is enclosed in a fiberglass radome, shown in figure 27, for weather protection. Provisions are also made for replacing the fiberglass radome with one having Frequency Selective Surface (FSS) characteristics for reduction of Radar Cross Section (RCS). Specifications for the AS-4127A are listed in table 5.

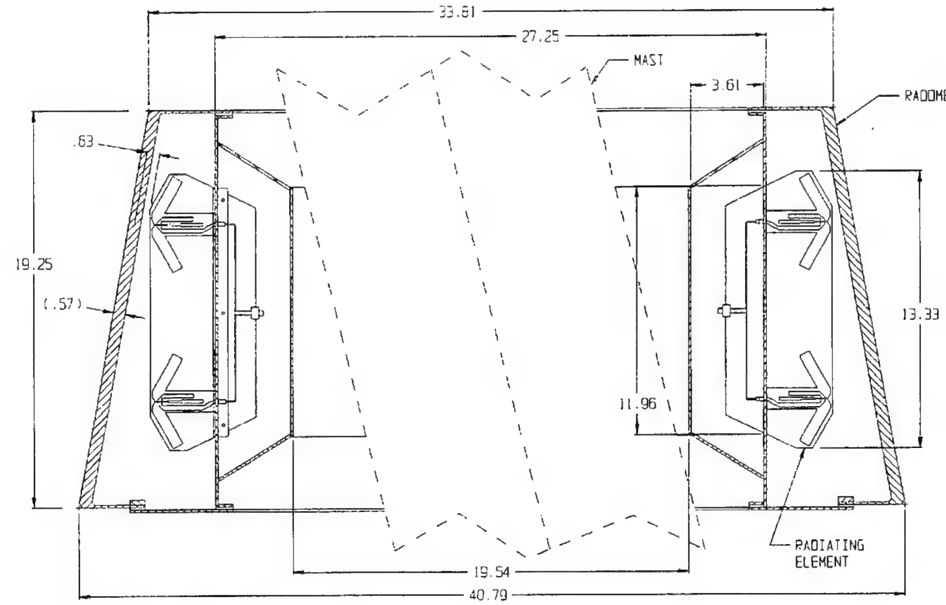


Figure 25. Cut-away drawing of AS-4127A.

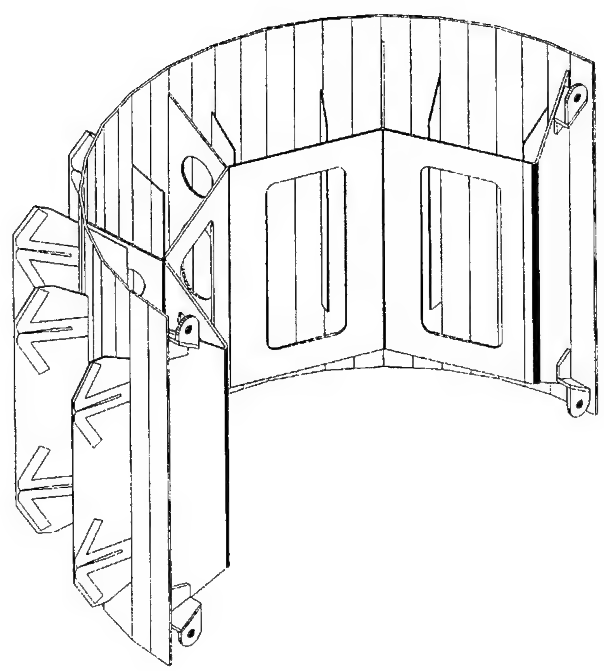


Figure 26. Sketch of AS-4127A cylindrical ground plane and radiating elements.

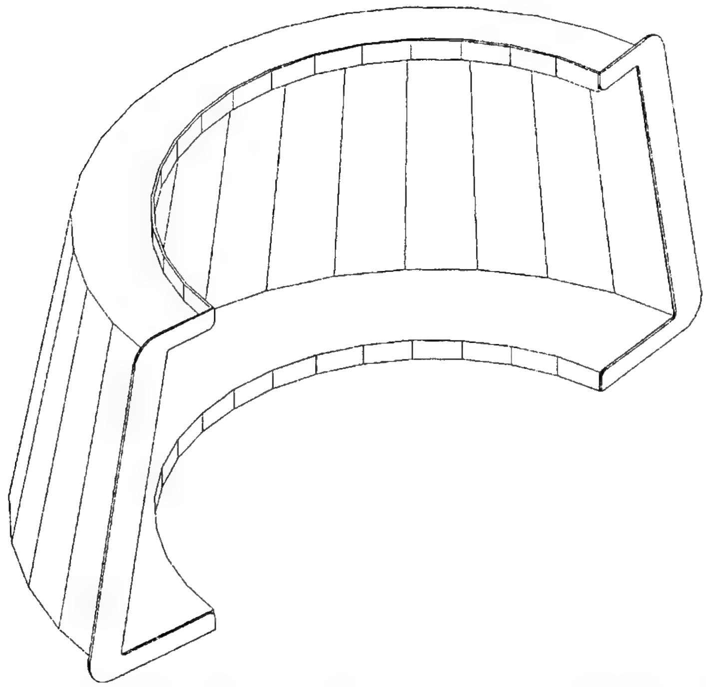


Figure 27. Sketch of AS-4127A radome.

Table 5. AS-4127/URC-107(V) JTIDS shipboard antenna specifications.

Parameter/Nomenclature	**Specification/Dimension**
Manufacturer	Naval Ocean Systems Center (now NRaD)
Part Number	AS-4127A/URC-107(V)
Size diameter/width, depth height	 43-inch diameter 19 inches
Weight	98 pounds
Operation	Continuous (24 hours/day)
Temperature operating nonoperating	 –28 °C to +65 °C –62 °C to +71 °C
Humidity	95% including condensation as water or frost
Radiation Pattern azimuth elevation HPBW	 Omnidirectional within ±1.0 dBi beam peak at horizon 30° minimum
Frequency Range	960 to 1215 MHz
Minimum Gain	2.0 dBi
Polarization	Vertical
Input Impedance (RF port, coaxial)	50 ohms
RF Power Input peak average	 1200 watts 140 watts
Voltage Standing Wave Radio (VSWR)	2.0:1 (maximum)

Table 5. AS-4127/URC-107(V) JTIDS shipboard antenna specifications. (Continued)

Parameter/Nomenclature	Specification/Dimension
Intermodulation Products	63 dB (below) primary signal level
Isolation from TACAN (with TACAN Choked installed)	40 dB
Mean-Time-Between-Failure	250,000 hours (minimum)

A view of the AS-4127A taken during environmental testing is shown in figure 28.

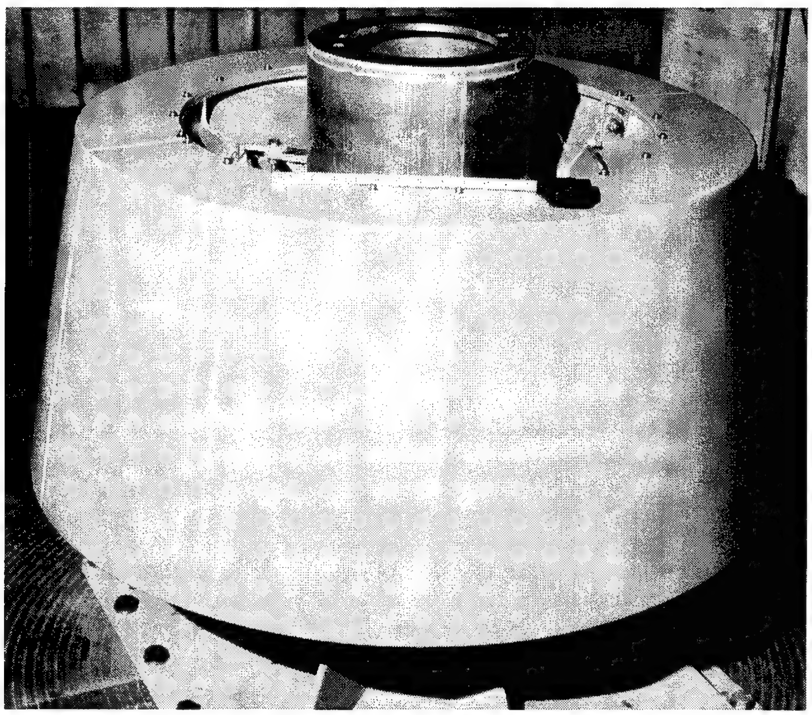


Figure 28. AS-4127A/URC-107(V) JTIDS shipboard antenna.

FREQUENCY SELECTIVE SURFACE (FSS) RADOME

The current specification for the AS-4127A antenna requires that an FSS radome be installed for selected applications. The characteristics of this radome are such that out-of-band signals are reflected skyward, thereby reducing the RCS of the antenna. Because of the diameter limitations of the antenna, it is necessary to locate the radome in the near field of the radiating elements. Due to this close proximity, a significant amount of energy is reflected off the radome and currents are induced in the copper surfaces of the FSS. These effects cause a loss to occur in the received and transmitted energy. The gain of the antenna is reduced, thereby decreasing the Effective Radiated Power (ERP), which adds to the link budget loss. The advantage of using the FSS radome for RCS reduction are offset by a decrease in ERP. Other disadvantages are a decrease in signal-to-noise ratio due to the loss of gain, and an increase in weight because of the larger radome containing the FSS surfaces.

Two configurations of FSS material are currently available—dipole and hexagonal. The dipole surface consists of copper strips printed on a dielectric material. See figure 29.

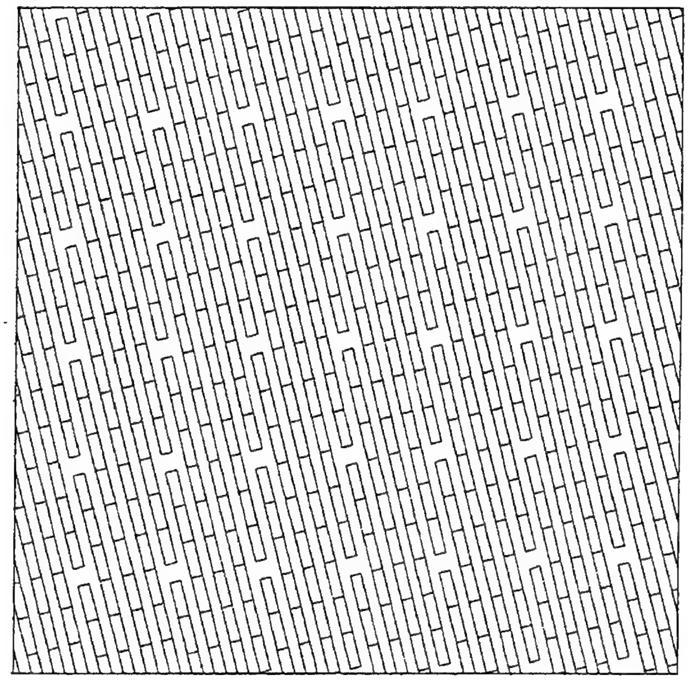


Figure 29. Dipole FSS radome material.

Two layers are used in the radome structure with the dipoles oriented orthogonally. This arrangement is shown in figure 30.

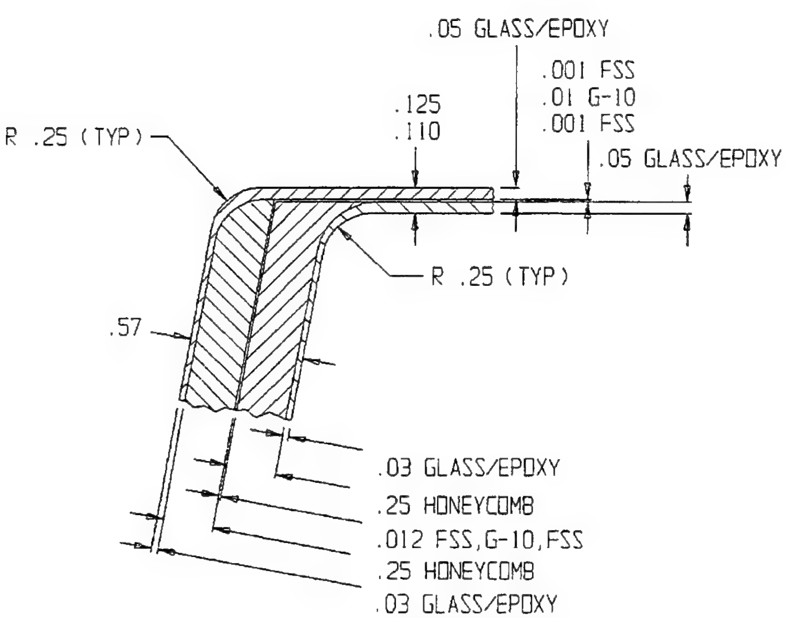


Figure 30. FSS radome cross section using dipole arrangement.

The hexagonal surface consists of hexagonal-shaped copper strips printed on a dielectric material. A sketch of this material is shown in figure 31. Two layers of this material are also used in the radome as shown in figure 32.

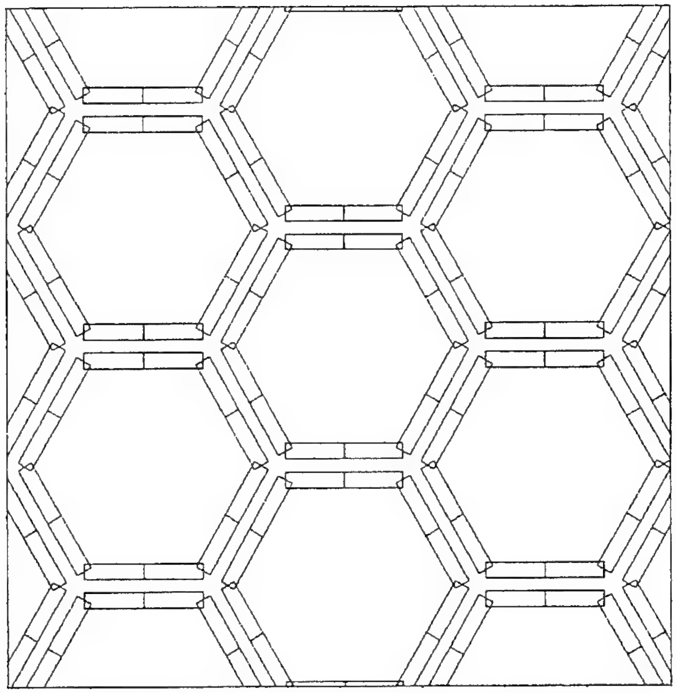


Figure 31. Sketch of hexagonal FSS material.

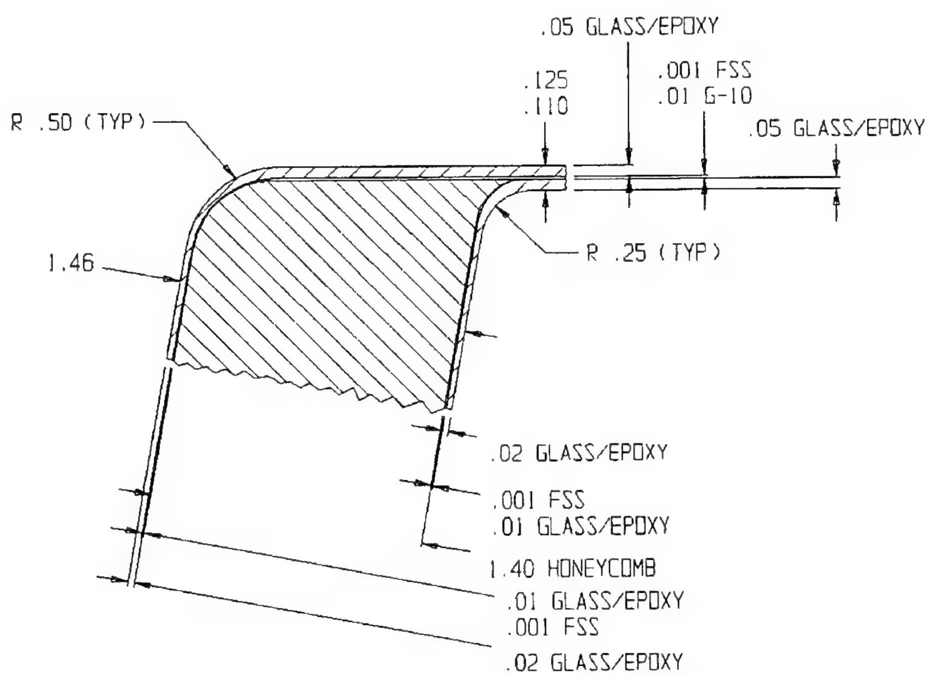


Figure 32. FSS radome cross section using hexagonal material.

Both types of material are being evaluated for effects on the radiation pattern of the antenna. Both materials provide acceptable RCS reduction performance.

AS-4127B/URC-107(V) JTIDS SHIPBOARD ANTENNA

The shipboard antenna was the first available component for the JTIDS system. Subsequently, other components were produced and qualified, and TECHEVAL/OPEVAL was conducted in FY 94. The terminal and associated components have shown JTIDS to be a sophisticated system much in advance of the antenna system. Improvements have been made in the antenna system to facilitate installation, and the elevation beam has had its energy maximized at the horizon. Other improvements are required to make the antenna system more flexible and adaptable to meet the sophistication of the terminal. These improvements will include increasing throughput and data-rate capability via increased antenna gain and directivity. As a result, exclusive target selection will result.

The exact method of beam control to be used in the AS-4127B will be determined in FY 96 and a prototype fabricated in FY 97. The determining factors will be associated with the functions required by the surface Fleet. Possible functions include, but are not limited to, AntiJam (AJ), burn-through, multiple beam, scan, stabilization, and adaptive control. Increases in weight, cost, and complexity will be the byproducts of sophistication.

Preliminary studies have shown that it is possible to obtain a gain of 10 dBi over a 25-degree azimuth sector, which is 6 dB greater than that available from the AS-4127A. Figure 33 illustrates a measured azimuth pattern for the AS-4127A using phase shift techniques at the radiating elements. This 10-dB increase of antenna gain would allow from a 6-dB increase of processing gain, thereby doubling the Link-16 throughput with no degradation of performance.

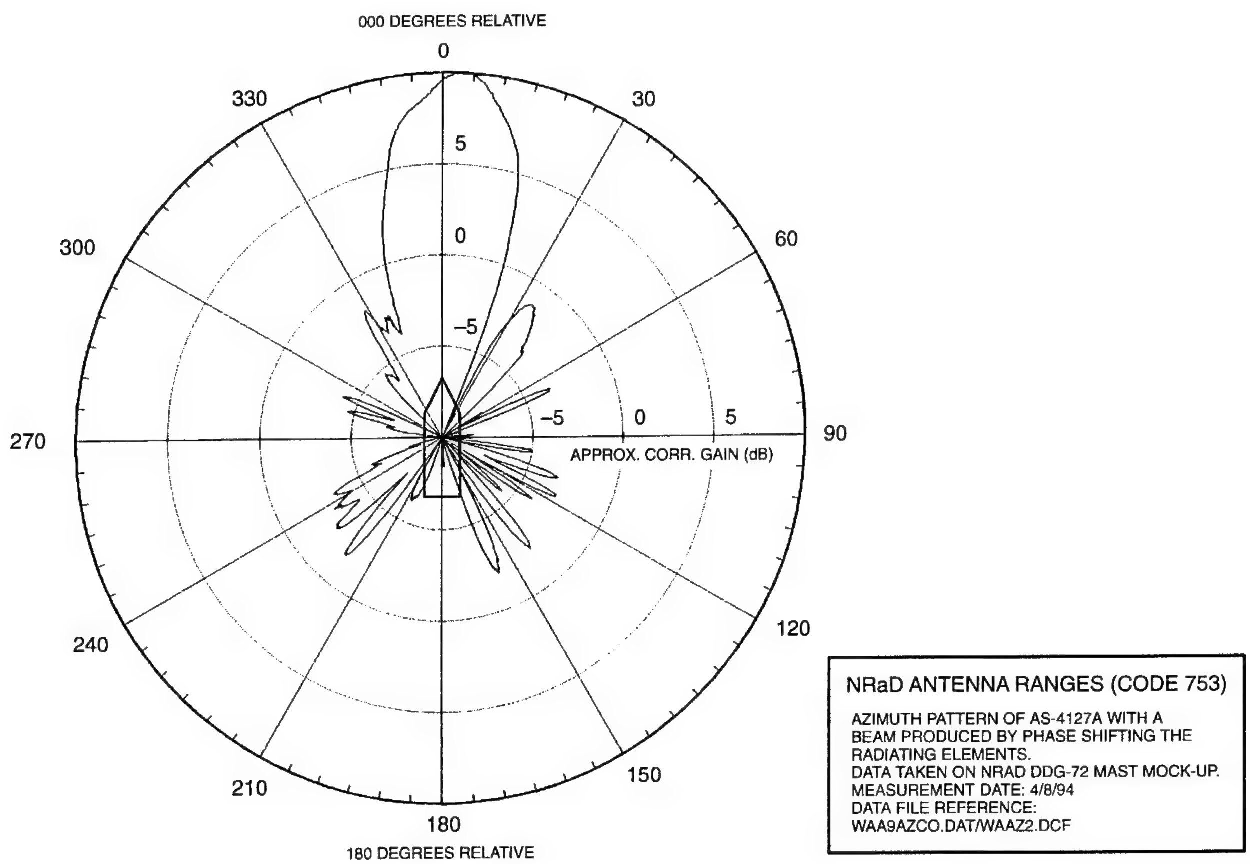


Figure 33. Measured azimuth pattern for AS-4127A using phase shift techniques.

A 7-dB null is possible over approximately a 30-degree azimuth sector. This technique was demonstrated with the AS-4127 resulting in the measured azimuth pattern shown in figure 34. A 5-dB null is possible over approximately a 90-degree azimuth sector using the same techniques. The off boresight jam margin may be reduced by 5 to 6 dB, with a potential increase in throughput resulting in better Low Probability of Intercept (LPI) and AJ performance.

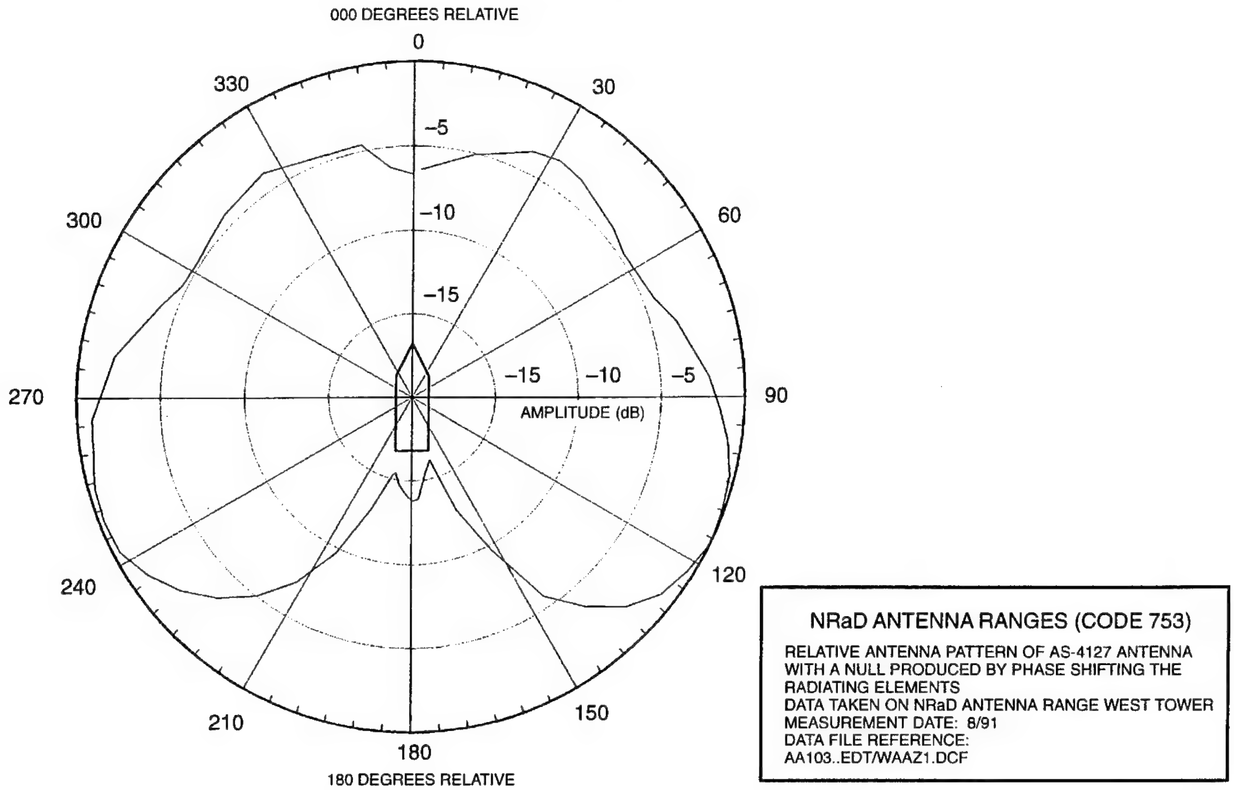


Figure 34. Measured azimuth pattern for AS-4127 using phase shift techniques.

A possible beam control technique using elemental phase shift control is shown in figure 35. This technique offers possibilities of achieving many of the functions discussed above.

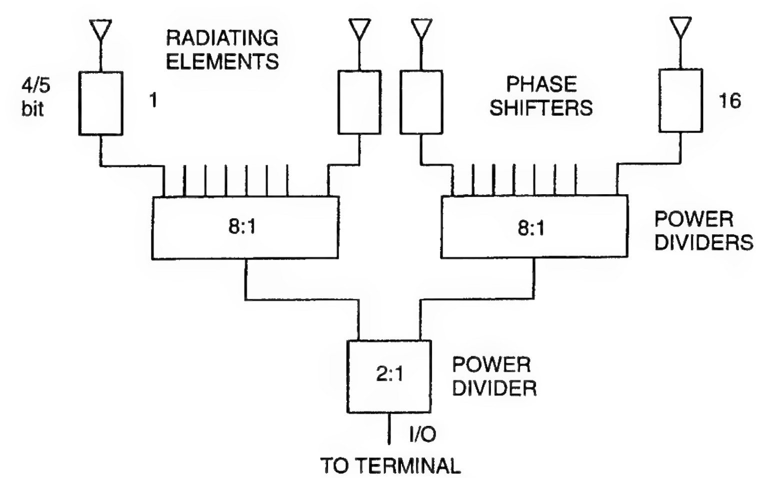


Figure 35. Beam control circuitry using elemental phase control.

JTIDS/TACAN DECOUPLING

Shipboard installation requirements dictated that the AS-4127 antenna was to be mast mounted immediately below the TACAN antenna. Because both systems essentially operate in the same frequency bandwidth, it was essential that they interfere with each other as little as possible. A NAVSEA requirement is that the RF coupling between antennas be no greater than –40 dB. A measurement of the coupling between the AS-4127 and TACAN antennas indicated that the maximum coupling was –35 dB. NRaD personnel determined that the coupling between antennas was caused by a surface wave. Studies by NRaD of methods to reduced this coupling led to the development of an RF choke, that, when placed at the underside of the outer rim of the TACAN antenna, reduced the coupling to a maximum of –42 dB. Figure 36 shows the measured coupling for the AS-4127/TACAN antennas.

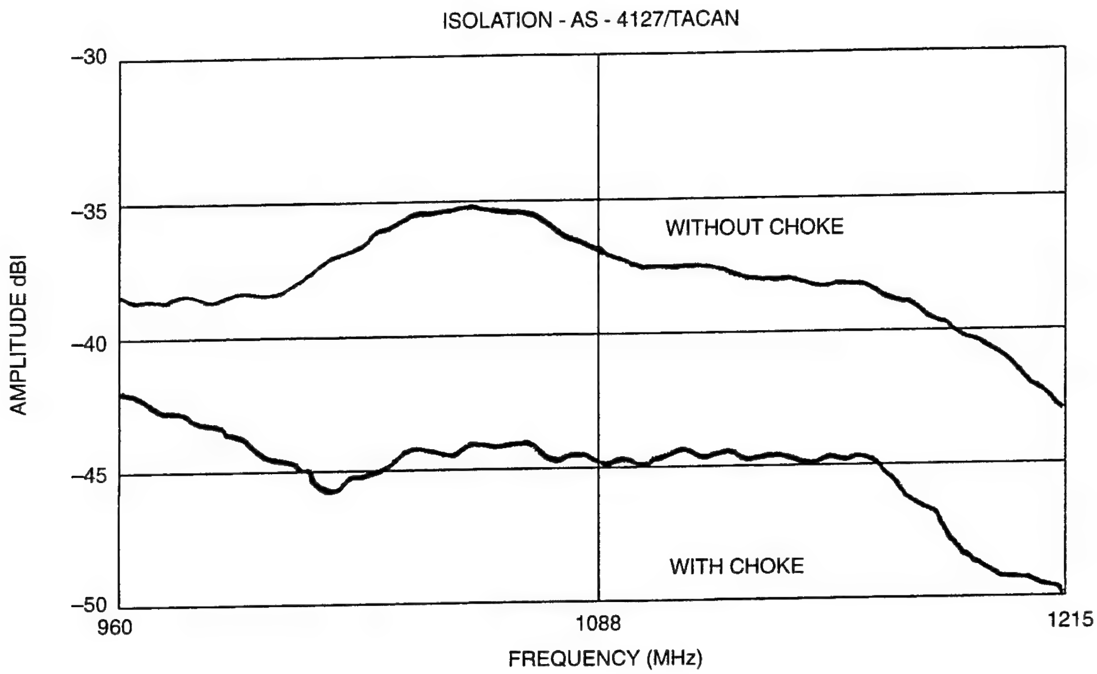


Figure 36. Measured coupling between AS-4127 and TACAN antenna.

The RF choke mounted on the TACAN antenna is shown in figure 37. A choke is included in the installation kit provided with each AS-4127 antenna.

Because of the possibility of the AS-4127A antenna being installed below the TACAN antenna, the coupling was also measured for the AS-4127A/TACAN arrangement. The results of those measurements are shown in figure 38 and indicate that the RF choke is also required with that antenna combination.

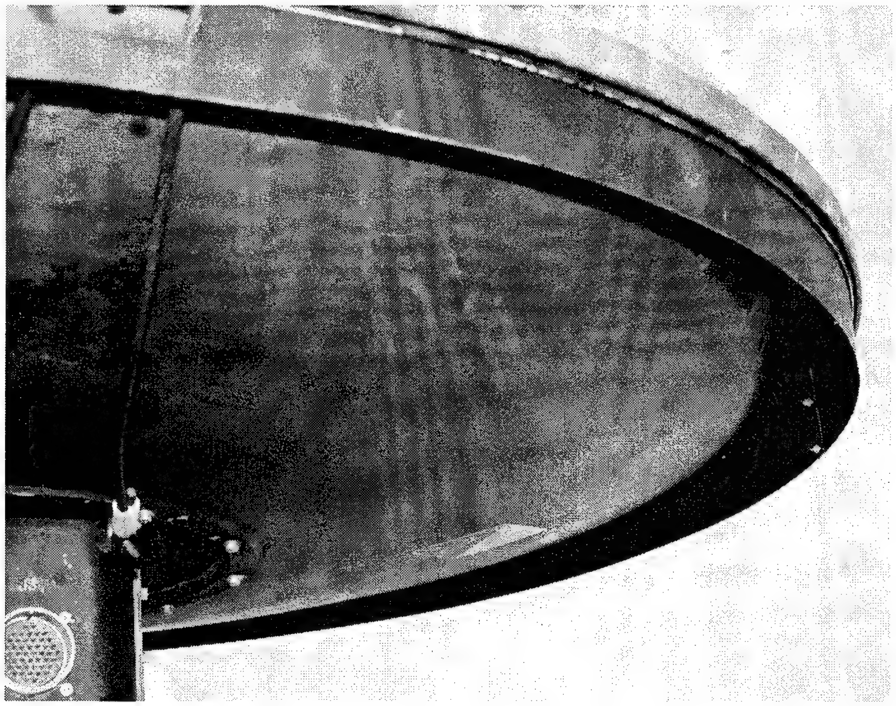


Figure 37. RF choke installed on TACAN antenna.

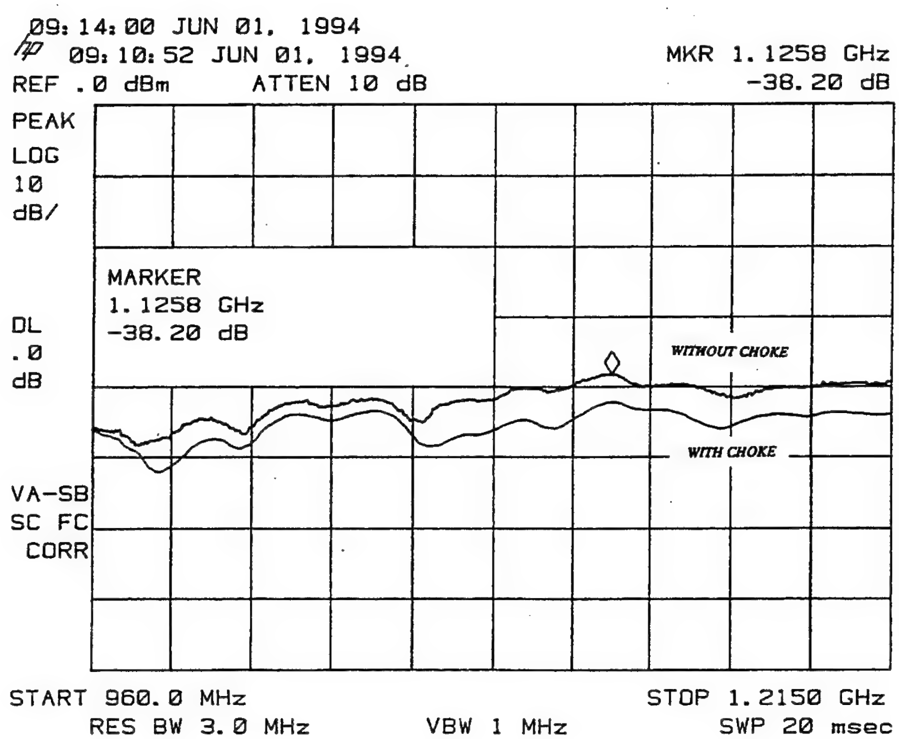


Figure 38. Measured coupling between AS-4127A and TACAN antenna.

NEAR-FIELD TEST DEVICE

To date, one reported JTIDS problem can be attributed to the antenna. The defect occurred in the power divider in the AS-4127 installed on the USS *Constellation* (CV 64). The result of this situation gave rise to Field Change (FC) #14. FC #14 was subsequently installed in all available AS-4127s. Other reported problems were not antenna faults, although at first look they appeared to be located at the antenna. All nonantenna problems were solved on site. The expense of removing an antenna from a ship's mast and transporting it to the NRaD test range can become prohibitive over a period of time.

To relieve this situation, NRaD developed a Near-Field Test Device capable of determining the operating condition of an AS-4127 on site. The device is portable and can be utilized at the installation site on a ship's mast or on the dock prior to removing the antenna from its shipping crate. The test device can also be used to determine if an antenna has been properly assembled prior to transporting it to a test range for evaluation.

The test device consists of two units, a transmitter and a receiver, each weighing not more than 8 pounds. The receive unit is connected to the RF port of the antenna and the transmitter unit is physically moved around the aperture. The device is battery operated (rechargeable). Two indications of fault are provided—audible and visual. Figure 39 shows the test device in use.

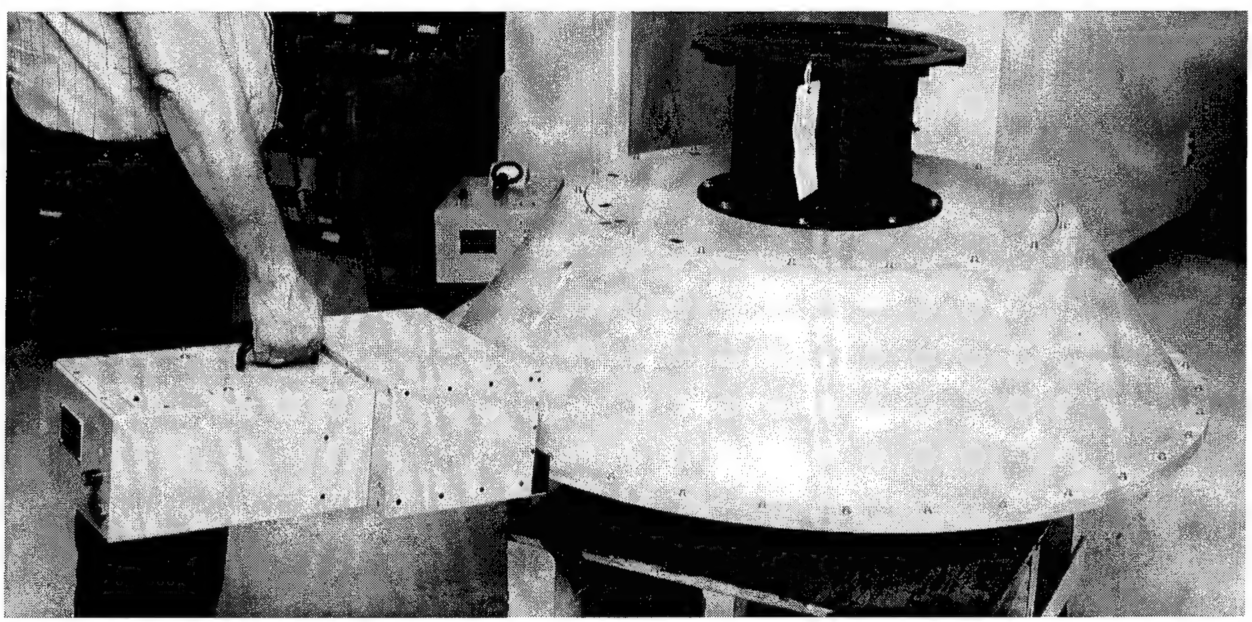


Figure 39. Near-field test device in use.

Future plans concerning the Near-Field Test Device include extending its capabilities to cover the entire JTIDS bandwidth. The current device operates at one frequency at the center of the JTIDS bandwidth. The development of a Near-Field Test Device for testing AS-4127A and AS-4127B antennas is also planned.

DDG 72 FLIGHT II MAST MOCKUP

NRaD was tasked by SPAWAR PMW-159 to fabricate a mockup of the O10 level of the DDG 72. The mockup was full scale and was to include all antenna systems in operating condition. A view of the mockup is shown in figure 40. The primary purpose for fabricating the mockup was to verify the operation of the "3-Antenna Approach." The "3-Antenna Approach" was an alternate JTIDS antenna configuration for this class of ship having a slanted mast not strong enough to support the weight of both the TACAN and the AS-4127 antennas. One antenna (transmit) was mounted on the O10 level and two similar antennas (receive) were mounted on the O7 level. The antennas to be used were the AS-4309 on the O10 level and the AS-4310 on the O7 level. The studies determined that the blockage offered by the mast to the transmit antenna on the O10 level was detrimental to the operation of the JTIDS system. Because of this, the "3-Antenna Approach" was cancelled.

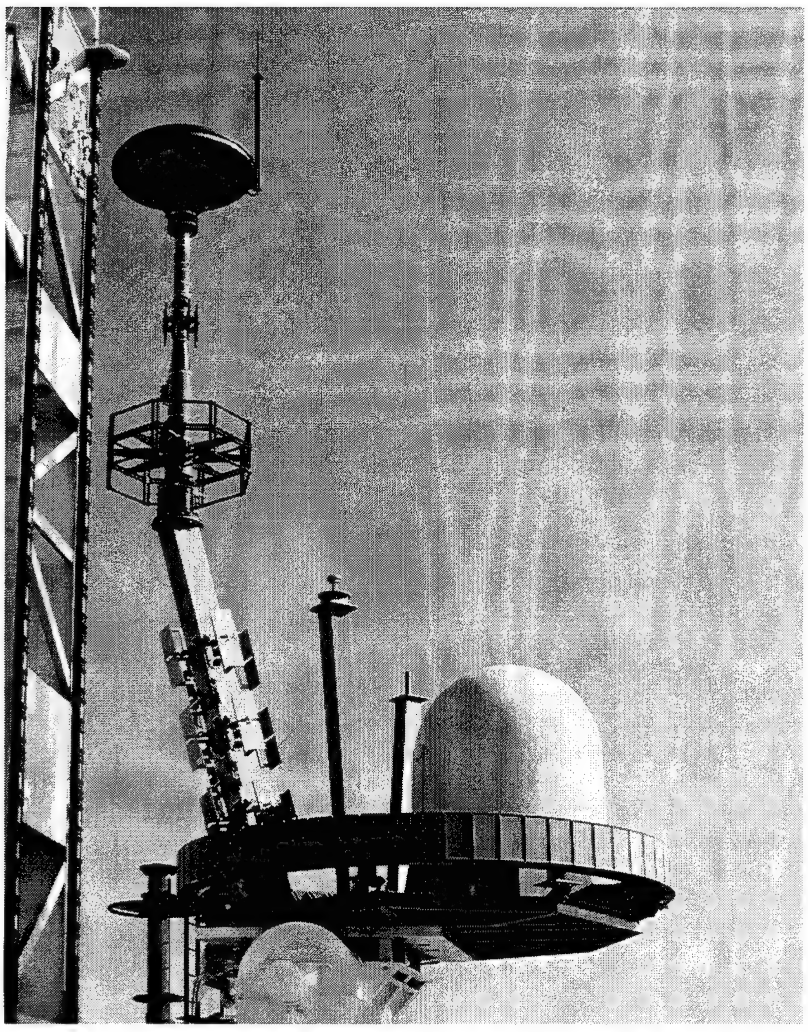


Figure 40. DDG 72 flight II mast mockup.

The development of the AS-4127A antenna offered a means of mounting an antenna system similar to the AS-4127 that could be mounted at other than the top of the mast location. The AS-4127A could be "wrapped around" the mast at a lower level but still maintain a clear field of view. Figure 41 shows the AS-4127A installed on the mast mockup. Extensive studies indicated that a minimum amount of interference would exist between the various antenna systems.

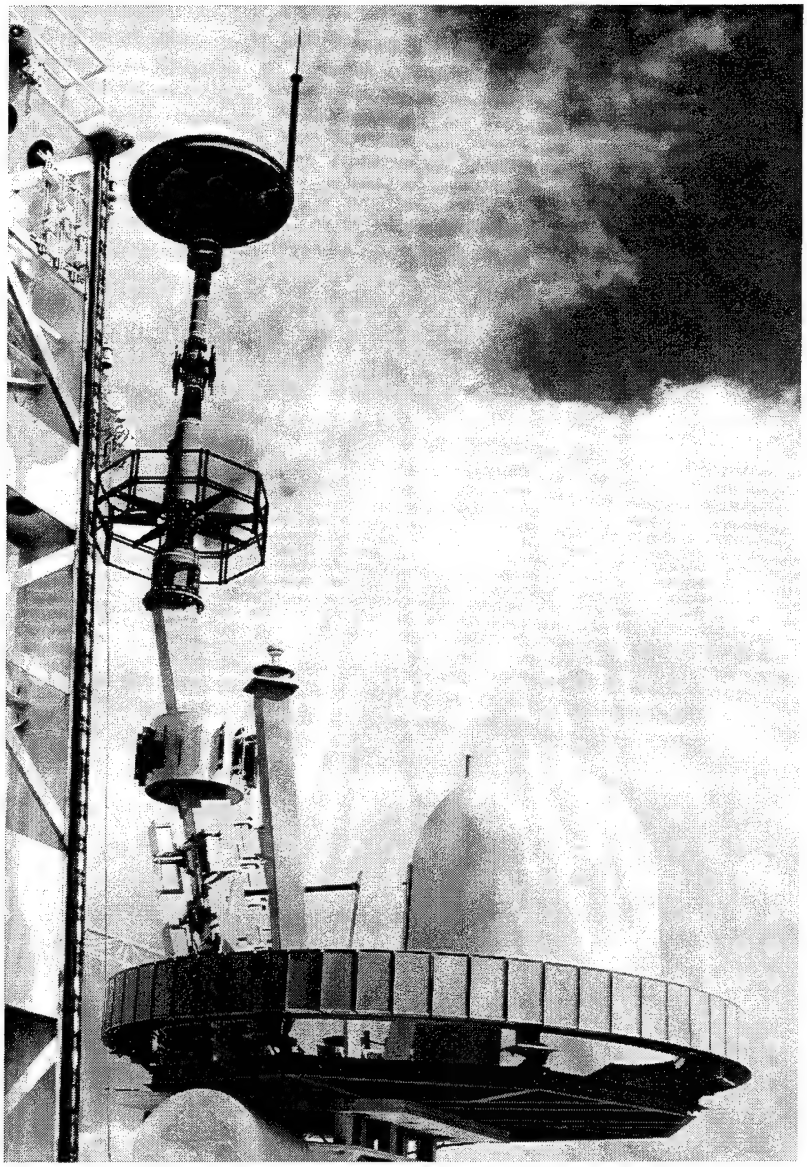


Figure 41. AS-4127A antenna mounted on DDG 72 mast mockup.

At the conclusion of the scheduled tests, the majority of the antenna systems were returned to the agencies that had provided them.

Future plans for the mockup include evaluation of the AS-4127A in the DDG 72 environment and LAMPS/CDF interference testing. Many of the antenna systems will be mockups for future testing. The mockup will be permanently installed on NRaD Building 583 at the south end of the Microwave Antenna Range, which offers a 180 degree view of the Pacific Ocean plus unobstructed views of San Clemente Island, Pedro Tower, and Building 600 SIF. RF links to Miramar Naval Air Station and North Island Naval Air Station are possible via the Pedro Tower.

SAN CLEMENTE ISLAND INSTALLATION

The purpose of the San Clemente Island installation is to allow the NRaD System Integration Facility (SIF) a wider operation area for JTIDS technical and operational evaluation. The design is such that it permits the installation of any portable JTIDS terminal system at the designated site. Two

antennas were permanently installed: one for transmit/receive and the one for receive-only. The installation allows for quick connection from the portable terminal to the antennas while providing the required RF radiation, personnel safety, and interference rejection.

The task began with a site visit in November 1992. The site was surveyed for installation criteria such as antenna location, power requirements, RF interference, and personnel safety. A proposed antenna location was selected.

Computer modeling of the proposed antenna configuration was completed. This was done for the transmit/receive antenna and the receive-only antenna.

A special bandpass filter for the transmit circuit was procured for JTIDS to ensure there was no interference between JTIDS subharmonics and the San Clemente Island UHF receivers.

Two “stand-alone” antennas (AS-4400), the yardarm supports, and cabling were designed and fabricated at NRaD. Due to its low loss characteristics, Andrew LDF5-50A type cable was used.

An Installation Plan was developed and a site visit in February 1993 verified the plan.

An RF junction box was fabricated. The junction box contains a bandpass filter for the transmit antenna RF cabling, a penetration for terminal input cables, a transmit sample/test port, and bulkhead connections for both antenna inputs.

A 208-volt three-phase AC power connection was installed to provide the required power to the portable JTIDS terminal.

The final installation occurred at San Clemente Island between 6-8 April 1993. The completion date was required for a technical evaluation start date of 27 April 1993.

Figure 42 shows the San Clemente Island antenna installation.

PEDRO TOWER INSTALLATION

The Pedro Tower Installation provides a Line-of-Site (LOS) link between the SIF and aircraft on the ground at NAS Miramar and NAS North Island. It can support three individual JTIDS vans for transmit and/or receive. The installation includes a “stand-alone” antenna, a notch filter assembly (NFA), high-power switching circuits, a Low Noise Amplifier (LNA), a 250-watt dummy loads, a 1:3 splitter (power divider), a power supply, and a DC converter. This installation has the potential for incorporating a full terminal and can operate as a complete JTIDS system.

The first test determined LOS with NAS Miramar. NAS North Island is visual LOS from Pedro Tower. This test consisted of mounting an L-band directional antenna on Pedro Tower and running pig-tailed Andrew LDF4-50 cable to the tower base. The base of the tower was set up with a sweep generator, a TWT, an isolator, a coupler, and a spectrum analyzer. Power density measurements were made at predetermined locations at the NAS Miramar Hanger #2 using a standard gain horn, an LNA, a bandpass filter, and a spectrum analyzer. The test data verified LOS between Pedro Tower and NAS Miramar.

The “stand-alone” antenna, the pole mast, the connector box, the wall mount, the control enclosure, and cabling were designed and fabricated at NRaD. AC power was installed at the tower for the installation.

Figure 43 shows the Pedro Tower antenna installation.

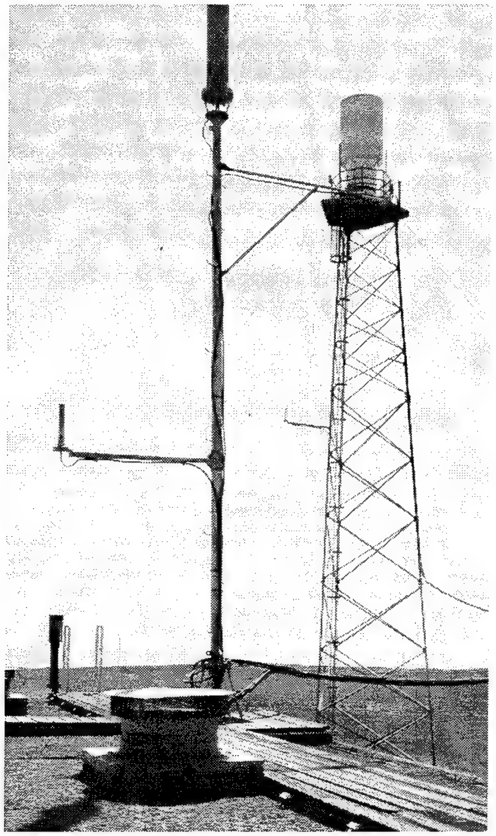


Figure 42. San Clemente Island antenna installation.

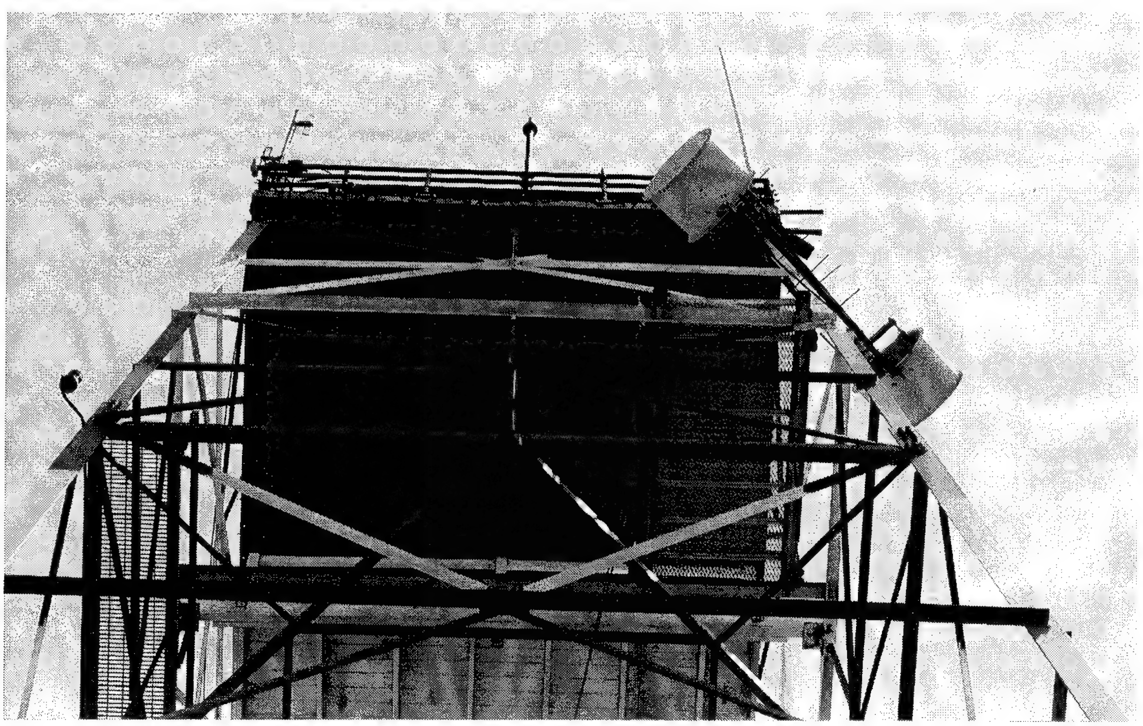


Figure 43. Pedro Tower antenna installation.

ACRONYMS

AC	Alternating Current
CDF	Combat Direction Finder
dB	Decibel
DTDMA	Distribution Time Division Multiplex Access
EDM	Engineering Development Model
EMC	Electromagnetic Compatability
EMI	Electromagnetic Interference
ERP	Effective Radiated Power
FCDSSA	Fleet Combat Direction System Support Activity
FSS	Frequency Selective Surface
HPBW	Half-Power BeamWidth
IFF	Identification Friend or Foe
ITT	International Telephone and Telegraph
JTIDS	Joint Tactical Information Data System
LNA	Low Noise Amplifier
LOS	Line of Sight
LPI	Low Probability of Intercept
MCTSSA	Marine Corps Tactical System Support Activity
MSC	Microwave Specialty Corporation
NAS	Naval Air Station
NAVSEA	Naval Sea System Command
NCCOSC	Naval Command, Control and Ocean Surveillance Center
NEC	Numerical Electromagnetic Code
NOSC	Naval Ocean Systems Center
NRaD	NCCOSC RDT&E Division
PEO	Program Executive Officer
RCS	Radar Cross Section
RF	Radio Frequency
SIF	System Integration Facility
SOCAL	Southern California
SPAWAR	Space and Naval Warfare Systems Command

TACAN	Tactical Air Navigation
TADIL	Tactical Digital Information Link
TAOC	Tactical Air Operations Center
UHF	Ultrahigh Frequency
VSWR	Voltage Standing Wave Ratio

BIBLIOGRAPHY OF DOCUMENTS PRODUCED BY NRAD CODE 753 IN SUPPORT OF PROJECTS FUNDED BY PEO, SCS, PMW-159-3D

AS-4400/URC

1. "Environmental Test Report for the JTIDS Stand-Alone Antenna RF Filter," 15 July 1994, W. R. Webster, NRaD, Code 811.
2. "Environmental Test Report for the JTIDS Stand-Alone Antenna," 20 June 1994, W. R. Webster, NRaD, Code 811.
3. "Use of the AS-4400/URC Antenna as the Primary JTIDS Antenna," 4 August 1994, J. Boyns, C. Dempsey, and H. Simonds, NRaD, Code 753.
4. "RF Power Test of AS-4400, AS-4309, and AS-4400/IFF Filter," 16 August 1994, Rod Cozad, NRaD, Code 753.
5. "JTIDS Stand Alone Antenna," A one page information sheet prepared for the Microwave Symposium, 24 May 1994, Rod Cozad, NRaD, Code 753.
6. "JTIDS Stand-Alone Antenna Traveler," 24 May 1994, Hale Simonds, Charles Dempsey, NRaD, Code 753, Jeanette Adams, NRaD, Code 892.
7. "Assignment of Joint Electronics Type Designation System (JETDS) Nomenclature," (AS-4400/URC), 12 July 1994, Naval Sea Logistics Center, 4130 S94-025, Ser N23/50145.
8. "Structural Evaluation of AS-4400/URC JTIDS Shipboard Antenna," January 1995, R. C. Shaw, NRaD TR 1689, Code 893.
9. "Level 3 Drawing Package for the AS-4400/URC Antenna," **(In Preparation),** Rolf Dahle, NRaD, Code 893.
10. "Prime Item Development Specification for AS-4400/URC JTIDS Shipboard Antenna," November 1994, NRaD TD 2713, Code 753.
11. "Interface Control Document for JTIDS Shipboard Antenna AS-4400/URC," November 1994, NRaD TD 2714, Code 753.
12. "AS-4400/URC JTIDS Shipboard Antenna," Brochure **(In Preparation)**, 1994, Dave Watry, NRaD, Code 893.
13. "Operations and Maintenance Manual for AS-4400/URC-107(V) JTIDS Shipboard Antenna," **(In Preparation),** 1994, NRaD, Code 753.

AS-4127A/URC-107(V)

1. "JTIDS AS-4127A/URC-107(V) and AS-4127B/URC-107(V) Shipboard Antennas Program Plan," 16 August 1994, J. Boyns, NRaD, Code 753.
2. "JTIDS Shipboard Antenna Adaptive Array Proposal," 31 March 1993, Hale Simonds, NRaD, Code 753.
3. "A Preliminary White Paper on: The Advantages of the NRaD JTIDS Passive Wrap-Around over the JTIDS DDG-72 Class - Three Antenna Configuration," 22 March 1994, Hale Simonds, NRaD, Code 753.
4. "Request for Nomenclature for the AS-4127A/URC-107(V) JTIDS Shipboard Antenna," Prepared 28 April 1994, Jeanette Adams, NRaD, Code 892.

5. "Prime Item Development Specification for JTIDS Wrap-Around Antenna, Version 1.0," 31 October 1993, Hale Simonds, NRaD TD 2712, Code 753.
6. "Structural Analysis of the AS-4127A Antenna," **(In Preparation),** 1994, R. C. Shaw, NRaD, Code 893.
7. "Interface Control Document for the JTIDS Shipboard Antenna AS-4127A," 1 September 1994, NRaD TD 2715, Code 753.
8. "Operations and Maintenance Manual for AS-4127A/URC-107(V) JTIDS Shipboard Antenna," **(In Preparation),** 1994, NRaD, Code 753.
9. "RF Interval Test Requirement of the AS-4127A/URC-107(V) Ser. #1A Shipboard Antenna Military Qualification," 22 March 1995, Rod Cozad, NRaD, Code 753.

AS-4127B/URC-107(V)

1. "Ideas to Consider for Phase Shift Modules for Adaptive Array Antenna (AS-4127B)," 29 June 1994, Rod Cozad, NRaD, Code 753..
2. "Adaptive Array Approaches Applicable to the JTIDS Shipboard Antenna (AS-4127/URC-107(V))," 14 August 1992, Hale Simonds, NRaD, Code 753

MAST MOCK-UP

1. "Structural Evaluation of TACAN/JTIDS/CDF Antenna Mast Assembly," NRaD TR 1671, September 1994, R. C. Shaw.
2. "DDG 72 Guided Missile Destroyer (DDG 51 Arleigh Burke Class) O10 Level Vertical Mast 'Adcock' Configuration; Stress Analysis of," 4 August 1994, M. A. Jones, NRaD, Code 813.
3. "DDG 72 Antenna Mast Mock-up," Brochure, December 1993, NRaD TD 2613, Code 753.
4. "Test Plan DDG 51 Class Flight II/IIA O10 Level Mast Mock-up," 20 September 1993, NRaD, Code 753.
5. "Coupling Measurements on the Mast Mock-up, Quick Look Report," 16 May 1994, NRaD, Code 753.
6. "A-1 Specification DDG 51 Flight II/IIA O10 Level Mast Mock-up," November 1992, NRaD, Code 753.
7. "NRaD Structure 416, North-South Range Antenna Tower, Wooden Platform; Overturn Moment Load Test Of," 14 February 1994, M. A. Jones, NRaD, Code 933.
8. "Interface Control Drawing for DDG-69 Shipboard Antenna," NRaD TD 2256, Revison A, August 1992, Dr. S-Y. Shih and R. Cozad.
9. "Mast Mock-up Final Report," **(In Preparation),** 1994, Dave Watry, NRaD, Code 893.
10. "Sight Selection for the Mast Mockup for Tech Eval & Op Eval on DDG 51 and Future Shipboard Simulations," 14 July 1994, NRaD Memo, R. Cozad, Code 753 and D. Watry, Code 893.

SUBMARINE

1. "USS Asheville JTIDS Modifications to the BRA-34 Antenna System Master Plan," 27 October 1993, NRaD, Code 753.
2. "Hardware and Radio Frequency Issues Related to a Permanent Submarine JTIDS Configuration," 25 May 1994, Hale Simonds, Charles Dempsey, NRaD, Code 753.

3. "USS Asheville Joint Tactical Information Distribution System (JTIDS) Radio Frequency (RF) Evaluation Test Plan," 9 August 1993, Hale Simonds, NRaD, Code 753.

AS-4127/URC-107(V)

1. "Environmental Test Report for the JTIDS AS-4127 Antenna Power Divider," 23 August 1994, W. R. Webster, NRaD, Code 811.
2. "A Study of Interference Lobes Produced by the AS-4127/URC-107(V) JTIDS Shipboard Antenna," 16 August 1994, J. Boyns, NRaD, Code 753.
3. "Post RF Performance of MIL-QUAL Modified Power Divider for AS-4127/URC-107(V) Antenna," 3 August 1994, R. E. Cozad, NRaD, Code 753.

EMI/EMC

1. "Reduction of Interference from JTIDS on DDG-71 Platforms Via NFA Utilization," 15 December 1993, Phil Love, NRaD, Code 752.

PREOPERATIONAL/OPERATIONAL SUPPORT

1. "FY 93 Pre-operational Support Final Report," September 1993, NRaD, Code 753.
2. "JTIDS Portable Lightweight CW and Sweep Generator," **(In Preparation),** 1994, R. E. Cozad, NRaD, Code 753.
3. "FY 94 Preoperational/Operational Support Final Report," **(In Preparation),** October 1994, J. Boyns, NRaD, Code 753.

NEAR-FIELD TEST DEVICE

1. "Operations Manual Near Field Test Unit for the AS-4127/URC-107(V) Shipboard Antenna," February 1994, R. E. Cozad, NRaD TD 2623.
2. "Near Field Test Unit for AS-4127A/URC-107(V)," **(In Preparation),** 1994, R. E. Cozad, NRaD, Code 753.

OTHER

1. "Joint Tactical Information Distribution System (JTIDS/Link 16) Terminal Video Demonstration Conducted on Board Naval Aircraft Based at the Naval Air Station, Brunswick, ME; Trip Report of," 9 September 1994, M. A. Jones, NRaD, Code 813.
2. "Brunswick, Maine Link-16 Install," 30 August 1994, NRaD Trip Report, C. Dempsey, Code 753.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1995	Final

4. TITLE AND SUBTITLE

JTIDS SHIPBOARD ANTENNAS

5. FUNDING NUMBERS

PR: CC54
PE: 0205604N
WU: DN213105

6. AUTHOR(S)

J. Boyns, Code 753 and Code 451

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Command, Control and Ocean Surveillance Center (NCCOSC)
RDT&E Division
San Diego, California 92152–5001

8. PERFORMING ORGANIZATION REPORT NUMBER

TD 2797

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Space and Naval Warfare Systems Command
Program Executive Office for Space, Communications and Sensors
(PMW–159–3D)
Washington, DC 20363–5100

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This document reports the development of the Joint Tactical Information Distribution System (JTIDS) program by NRaD Code 753 (formerly NOSC Code 8112) and the former NOSC Code 831 beginning in FY 84.

14. SUBJECT TERMS

Joint Tactical Information Distribution System (JTIDS)
Communications
Tactical Data Link
Command Control

15. NUMBER OF PAGES

49

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAME AS REPORT

21a. NAME OF RESPONSIBLE INDIVIDUAL	21b. TELEPHONE *(include Area Code)*	21c. OFFICE SYMBOL
J. Boyns	(619) 553-2578	Code 753

INITIAL DISTRIBUTION

Code 0012	Patent Counsel	(1)
Code 0271	Archive/Stock	(6)
Code 0274	Library	(2)
Code 70	T. F. Ball	(1)
Code 75	J. E. Griffin	(1)
Code 753	R. W. Major	(1)
Code 753	J. E. Boyns	(100)

Defense Technical Information Center
Alexandria, VA 22304–6145 (4)

NCCOSC Washington Liaison Office
Washington, DC 20363–5100

Center for Naval Analyses
Alexandria, VA 22302–0268

Navy Acquisition, Research and Development
Information Center (NARDIC)
Arlington, VA 22244–5114

GIDEP Operations Center
Corona, CA 91718–8000